SHIELDS RIVER WATERSHED WATER QUALITY PLANNING FRAMEWORK AND SEDIMENT TMDLS

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EXECUTIVE SUMMARY

The Shields River Watershed lies in south-central Montana, just north of Livingston and 13 miles northeast of Bozeman. The watershed encompasses 855 square miles (547,048 acres), mostly within Park County, but includes portions of Gallatin and Meagher counties. The Bridger and Bangtail Mountains confine the watershed to the west and the Crazy Mountains form the eastern watershed boundary. The Shields River flows in a southerly direction for approximately 62 river miles to the confluence with the Yellowstone River near Livingston, Montana. Major tributaries to the Shields River include Elk Creek, Cottonwood Creek, Rock Creek, Potter Creek, and Smith Creek. Elevations in the watershed range from approximately 10,850 ft (3307 m) in the Crazy Mountains to 4,386 ft (1337 m) at the mouth of the Shields River.

The Clean Water Act (CWA) requires the development of Total Maximum Daily Loads (TMDLs) that will provide conditions that can support all identified uses. This document combines a generalized watershed restoration strategy along with creation of TMDLs. The designated water uses include drinking, culinary and food processing after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply. CWA objectives include restoration and maintenance for all of these uses. In the Shields River Watershed, the most sensitive uses are the fishery and aquatic life.

A TMDL is a pollutant budget identifying the maximum amount of a particular pollutant that a water body can assimilate without causing applicable water quality standards to be exceeded. Section 303 of the Federal CWA and Section 75-5-703 of the Montana Water Quality Act (WQA) require development of TMDLs for impaired water bodies that do not meet Montana water quality standards. Section 303(d) also requires identification of impaired water bodies on a list, referred to as the 303(d) List. This 303(d) List is updated every two years and submitted to the U.S. Environmental Protection Agency (EPA) by the Montana Department of Environmental Quality (DEQ[1]).

In 1996, the entire Shields River and 5 tributaries were listed on the 303(d) List as threatened or partially supporting their beneficial uses. Since 1996, the Shields River, Rock Creek, and Cottonwood Creek have each been split into two water body segments, each being reviewed separately on the 303(d) List. Although there have been some changes to the probable impairment causes, the 2006 303(d) List includes the same water bodies as the 1996 303(d) List, but the upper segment of Rock and Cottonwood Creeks are listed as fully supporting their beneficial uses. This document focuses on sediment impairments in Shields River Watershed. TMDLs are provided for the Shields River and Potter Creek.

Source assessments identify agriculture, historical timber harvest, historical riparian vegetation removal, bank erosion, and roads as the primary sources of human caused pollutants in the Shields River Watershed. Restoration strategies for the Shields River TPA focus on implementing agricultural and road management BMPs, timber harvest BMPs, and other land, soil, and water conservation practices that relate to near stream channel and vegetation

[1] DEQ refers to the Montana Department of Environmental Quality unless otherwise noted.

conditions. Restoring instream flow to dewatered tributaries is another critical component to restoration of the Shields River Watershed.

The restoration process identified in this document is voluntary, cannot divest water rights or private property rights, and does not financially obligate identified stakeholders unless such measures are already a requirement under existing Federal, State, or local regulations.

Restoration strategies identified in this document are intended to balance the varying uses of water while adhering to Montana's water quality and water use laws. This document should be considered dynamic, by providing an "adaptive management strategy" approach to restore water quality in the Shields River Watershed. This water quality plan is intended to identify the knowledge we have at present and to identify a future path for water quality restoration. As more knowledge is gained through the restoration process and future monitoring, this plan may change to accommodate new science and information. Montana's water quality law provides an avenue for using the adaptive management process by providing for future TMDL reviews.

The state is required to support a voluntary program of reasonable land, soil, and water conservation practices. DEQ's approach to this program recognizes that the cumulative impacts from many nonpoint source (NPS) activities are best addressed via voluntary measures with DEQ and/or other agency or other forms of professional assistance. This often applies to agricultural situations or small landowner activities along or near streams. The State's voluntary program does not cover all NPS activities since there are local, state and/or federal regulations that apply to certain NPS activities within Montana. Examples where a non-voluntary approach is applicable due to existing regulations include but are not limited to streamside management zone requirements for timber production, minimum septic design and location requirements, local zoning requirements for riparian or streambank protection, and compliance with 310 Law.

The document structure provides specific sections that address TMDL components and watershed restoration. **Sections 1.0 through 4.0** provide background information about stakeholder involvement, the Shields River Watershed, Montana's water quality standards, and Montana's 303(d) Listings. **Section 5.0** provides TMDL targets, existing data, and the impairment status for each water body. **Sections 6.0 and 7.0** review sediment source assessments, TMDLs, and allocations. Generalized restoration strategy and follow up monitoring approach are provided in **Section 8.0**. **Section 9.0** is a review of stakeholder and public comment periods during the TMDL process. Many of the detailed technical analyses are provided in appendices. **Table E-1** provides a very general summary of the water quality restoration plan and TMDL contents.

Table E-1. Water Quality Plan and TMDL Summary Information.

Impaired Water Body Summary	• The focus of this document is sediment-related impairments. Two of the three water bodies listed on the 1996 and 2006 303(d) Lists as impaired from sediment-related causes have TMDLs presented in this document. The following TMDLs are included in this Water Quality Planning Framework: o Shields River and Potter Creek • Data suggest the Antelope Creek listing is actually a nutrient-related impairment, and a TMDL has not been prepared at this time. The impairment will be addressed during future development of nutrient-related TMDLs within the Shields River TMDL Planning Area
Impacted Uses	• Coldwater fishery and aquatic life beneficial uses are negatively impacted from sedimentation
Pollutant Source Descriptions	• Roads and transportation: Forest, Federal, and County roads. Sediment production from unpaved roads, stream crossings, and stream encroachment from all road types. • Agriculture: Historic harvest of riparian vegetation. Extensive areas of grazing, cultivation, and irrigation. • Silviculture: Historic logging practices.
TMDL Target Development Focus	• Fine sediment in riffles and spawning substrate compared to reference condition • Channel conditions that affect sediment transport compared to reference condition • Biological indicators compared to reference condition • Presence of significant human caused sources
Other Use Support Objectives (non-pollutant & non-TMDL)	• Improve native riparian vegetation cover. • Improve instream fishery habitat. • Improve instream flow. • Eliminate unnatural fish passage barriers based on fishery goals.
Sediment TMDL and Allocation Summary	• Load allocations (LA) provided for roads, hillslope erosion (by subwatershed and land cover), bank erosion, and natural background. • An overall percent sediment load reduction is provided for the TMDL and is based on individual percent reduction allocations and also natural background estimates. Estimated annual sediment LAs to all significant source categories are also provided. Reductions are based on estimates of BMP performance. The annual TMDL is the sum of the allocations. Numeric sediment load based daily TMDLs and daily allocations are also estimated and provided in an appendix. • Manage the stream corridor to facilitate transport of excess historical sediment loads through the system (not a "formal" TMDL load allocation, but an important load consideration).
Sediment Restoration Strategy	• The restoration strategy identifies general restoration approaches for assessed sources. Addressing the sources in the restoration strategy will likely achieve TMDLs. An adaptive management component is also provided for determining if future restoration will meet targets provided in the document.

SECTION 1.0 INTRODUCTION

1.1 Watershed Overview

The Shields River Watershed is located in south-central Montana, just north of Livingston and 13 miles northeast of Bozeman. The watershed encompasses 855 square miles (547,048 acres) mostly within Park County, but includes portions of Gallatin and Meagher counties. The major water body in the watershed is the Shields River, which flows from North to South for approximately 62 river miles to the confluence with the Yellowstone River near Livingston, Montana. Major tributaries to the Shields River include Elk Creek, Cottonwood Creek, Rock Creek, Potter Creek, and Smith Creek. Additional characteristics of the Shields River Watershed are discussed in **Section 3.0** of this document (Watershed Characterization).

The Shields River Watershed (also referred to in this document as the Shields River TMDL Planning Area, or TPA) is one of more than 90 TPAs in Montana in which water quality is listed as impaired. In each of these TPAs, the State of Montana is required to develop TMDLs to reduce pollutant loading and eliminate other negative impacts to water quality in impaired water bodies.

1.2 TMDLs and the Water Quality Planning Framework Process

A TMDL is the total amount of pollutant a stream may receive from all sources without exceeding water quality standards. A TMDL is also a reduction in pollutant loading resulting in attainment of water quality standards. Section 303 of the Federal CWA and the Montana WQA (Section 75-5-703) requires development of TMDLs for impaired water bodies that do not meet Montana water quality standards. Although water bodies can become impaired from pollution (e.g. flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, and metals), the EPA limits TMDL development to waters impaired by pollutants (Dodson 2001). Section 303 also requires states to submit a list of impaired water bodies to the EPA every two years. Prior to 2004, the EPA and the Montana DEQ referred to this list as the 303(d) List. Since 2004, the EPA has requested that states combine the 303(d) List with the 305(b) Report containing an assessment of Montana's water quality and its water quality programs. The EPA refers to this new combined 303(d)/305(b) Report as the Integrated Water Quality Report.

The TMDL development process is a problem-solving approach that results in a framework for water quality improvement. The primary objective is to develop an approach to restore and maintain the physical, chemical, and biological integrity of streams in the TPA so they will support all uses identified in state water quality standards. The uses include drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply. The major steps of the TMDL development process generally include defining the problem, quantifying the pollutant sources, determining the pollutant loading conditions needed to solve the problem, and developing a monitoring strategy.

Although not a required TMDL development step, most Montana TMDL development documents include a section on implementation and restoration planning.

These TMDL development steps are further summarized below. Although they are presented sequentially, some of the steps tend to overlap due to the nature of this problem solving approach.

Defining the Problem:

First, the water quality problems of concern are thoroughly evaluated and described. This includes understanding the characteristics and function of the watershed, documenting the location and extent of the water quality impairments, and identifying the likely causes and sources of impairment. Water quality targets are developed for each pollutant of concern during this step to gain a better understanding of stream health. These targets typically include a suite of in-stream measures that link directly to the impacted beneficial use(s) and applicable water quality standard(s). The water quality targets help define the desired stream conditions and are used to provide benchmarks to evaluate overall success of restoration activities. The water quality targets also provide a means to evaluate the extent of the problem by comparing existing stream conditions to the desired target values.

Quantifying Pollutant Sources (Source Assessment):

Second, all significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Source assessments often have to evaluate the seasonal nature and ultimate fate of the pollutant loading since water quality impacts can vary throughout the year. The source assessment usually helps to further define the extent of the problem by putting human caused loading into context with natural background loading.

A pollutant load is usually quantified for each point source permitted under the MPDES program. Most other pollutant sources, typically referred to as nonpoint sources, are quantified by source categories such as unpaved roads and/or by land uses such as crop production or forestry. These source categories or land uses can be further divided by ownership such as Federal, State, or private. Alternatively, a sub-watersheds or tributaries approach can be used whereby most or all sources in a sub-watershed or tributary are combined for quantification purposes.

The source assessments are performed at a watershed scale because all potentially significant sources of the water quality problems must be evaluated. The source quantification approaches may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading (40CFR Section 130.2(I)). Montana TMDL development often includes a combination of approaches depending on the level of desired certainty for setting allocations and guiding implementation activities.

Determining Acceptable Pollutant Loading Conditions:

The next step is defining the allowable loading for each pollutant of concern. This allowable loading is the TMDL. The TMDL is the assimilative capacity for the water body and reflects the sum total of acceptable loading conditions for all of the pollutant loading sources. This sum total of acceptable loading is typically sub-divided into individual allocations applied to human activities and natural background loading in the watershed, often expressed in the form of a percent load reduction. The allocations are based on the existing pollutant loading conditions determined during source assessment and a determination of practical and achievable load reductions via application of reasonable land, soil, and water conservation practices.

TMDL Implementation and Restoration Planning:

Most of Montana's TMDL documents also include an implementation section. Once the necessary pollutant loading conditions to solve the problem are identified, implementation of measures to reduce pollutant loading is vital to the achievement of the TMDL. The allocations provide the basis for TMDL implementation since the allocations are based on the application of reasonable land, soil, and water conservation practices.

Although DEQ provides TMDL implementation assistance and some implementation components may be regulatory, TMDL implementation primarily relies on the support of watershed landowners and various stakeholders. Montana DEQ supports a policy of voluntary compliance for addressing many of the nonpoint sources of pollutants emanating from private lands. Water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or local regulations.

For prioritizing implementation efforts, watershed groups and other stakeholders can focus on the sources that have the highest achievable loading reductions captured within the allocations, and apply the reasonable land, soil, and water conservation practices that were used to determine the load reduction potential. The applicable land, soil, and water conservation practices in many watersheds, such as the Shields, are similar or equivalent to best management practices (BMPs) that can be applied to agricultural or other land management activities. In some cases, additional conservation practices may be necessary to achieve compliance with water quality standards and restore beneficial uses.

Developing a Monitoring Strategy:

A monitoring strategy is a primary part of adaptive management and usually considered part of the TMDL margin of safety (MOS), which is a required TMDL component. The monitoring strategy typically includes a monitoring design to evaluate progress in meeting the water quality targets established during TMDL development. A variety of monitoring recommendations regarding progress toward meeting allocations is also typically included so that relationships between pollutant load reductions and in-stream water quality target parameters can be evaluated over time. This information can be used to help fine-tune TMDL implementation and restoration planning as discussed above.

1.3 303(d) List Summary and TMDLs Written

By federal court order, DEQ must address all pollutant/water body combinations appearing on the 2006 303(d) List that were also identified on the 1996 303(d) List. The focus of this document is sediment-related impairments, and there are three water bodies within the Shields River TPA that have sediment-related listings on the 2006 303(d) Lists: the Shields River which consists of two separate water body segments, Potter Creek, and Antelope Creek (**Table 1-1**; DEQ, 2006a). TMDLs have been completed for the Shields River and Potter Creek. Sediment-related impairment can be associated with siltation, sedimentation, and suspended sediment and is further discussed for each water body in **Section 5.0**. Data collected to assist with TMDL development suggest the Antelope Creek sediment-related listing is actually more likely due to nutrient-related impairment, and a TMDL has not been prepared at this time. The impairment will be addressed at a later date during development of nutrient-related TMDLs within the Shields River TPA.

Table 1-1. Summary of 2006 303(d) Listings and TMDL Status
Shaded rows contain water bodies with either a pollution-only listing or a pollutant listing that was on the 2006 List but not on the 1996 303(d) List. Pollutant-related causes of impairment are in bold.

Stream Assessment Unit	Probable Cause	2006 303d	1996 303d	TMDL Development Schedule	2008 TMDL Review	TMDL Completed	Further Impairment Review Recommended
Antelope Creek MT43A002_020	**Solids (suspended/bedload)**	X	X	2012	X	No	Yes
	Alteration in streamside or littoral vegetative covers	X		N/A*	N/A	N/A	N/A
	Excessive algal growth**	X		2016	No	No	Yes
Cottonwood Creek (headwaters to Trespass Cr) MT43A002_032	Flow alteration	FS	X	N/A*	N/A	N/A	N/A
Cottonwood Creek (Trespass Cr to mouth) MT43A002_031	Low flow alteration	X	X	N/A*	N/A	N/A	N/A
Elk Creek MT43A002_040	Alteration in streamside or littoral vegetative covers	X		N/A*	N/A	N/A	N/A
Potter Creek MT43A002_10	**Sedimentation/Siltation; Solids (suspended/bedload)**	X	X	2012	X	Yes	No
Rock Creek (headwaters to USFS boundary) MT43A002_052	Flow alteration	FS	X	N/A*	N/A	N/A	N/A
	Other habitat alterations	FS	X	N/A*	N/A	N/A	N/A
Rock Creek (USFS boundary to mouth) MT43A002_051	Low flow alteration	X	X	N/A*	N/A	N/A	N/A
Shields River	**Sedimentation; Siltation; Suspended Solids**	X	X	2012	X	Yes	No
(headwaters to	Low flow alteration	X	X	N/A*	N/A	N/A	N/A
Cottonwood Cr) MT43A001_012	Other habitat alterations; Alteration in streamside or littoral vegetative covers;	X	X	N/A*	N/A	N/A	N/A

Table 1-1. Summary of 2006 303(d) Listings and TMDL Status
Shaded rows contain water bodies with either a pollution-only listing or a pollutant listing that was on the 2006 List but not on the 1996 303(d) List. Pollutant-related causes of impairment are in bold.

Stream Assessment Unit	Probable Cause	2006 303d	1996 303d	TMDL Development Schedule	2008 TMDL Review	TMDL Completed	Further Impairment Review Recommended
	Physical substrate habitat alterations						
Shields River (Cottonwood Cr to mouth) MT43A001_011	**Sedimentation; Siltation; Suspended Solids**	X	X	Yes	X	Yes	No
	Low flow alteration	X	X	N/A*	N/A	N/A	N/A
	Other habitat alterations; Alteration in streamside or littoral vegetative covers; Physical substrate habitat alterations	X	X	N/A*	N/A	N/A	N/A

FS = fully supporting all beneficial uses
* - TMDLs are not required for pollution-related impairment and are not pursued for fully supporting stream segments.
** - Algal growth is often linked to an excess in nutrient pollutant loading. Therefore, a nutrient TMDL could be required to satisfy future TMDL schedule requirements.

All 303(d) listing probable causes shown in **bold** in **Table 1-1** (i.e. siltation, sedimentation, suspended solids, etc) are associated with sediment and will be addressed as sediment-related impairments within this document. Although TMDLs address pollutant loading, implementation of land, soil, and water conservation practices to reduce pollutant loading will inherently address some pollution impairments in the listed water bodies above.

1.4 Potential Future TMDL Development

Additional data collection and analysis was completed for pollutants within several water bodies where impairment conditions were suspected, but had not been previously confirmed during application of DEQ's assessment process using methods consistent with State Law (75-5-702). The results from this work will be made available in the DEQ files, and could lead to additional TMDL development at a later time for these and possibly other water body – pollutant combinations. The water body – pollutant combinations that underwent additional assessment include:

Shields River (upper segment) – nutrients
Shields River (lower segment) – nutrients
Elk Creek – sediment
Cottonwood Creek (lower segment) – sediment
Rock Creek (lower segment) – sediment

1.5 Document Organization

This document is a water quality planning framework that includes TMDLs. This document focuses on sediment-related water quality impairments in the Shields River TPA. The document is structured to address all of the required components of a TMDL and also includes an implementation and monitoring strategy as well as a discussion on public involvement. It is organized as follows:

- Stakeholder and Public Participation: **Section 2.0**
- Watershed Characterization: **Section 3.0**
- Application of Montana's Water Quality Standards for TMDL Development: **Section 4.0**
- Comparison of Existing Data to Water Quality Targets: **Section 5.0**
- Pollutant Sources and Load Estimates: **Section 6.0**
- TMDL, Allocations, and Margin of Safety: **Section 7.0**
- Restoration and Monitoring Strategy: **Section 8.0**
- Stakeholder and Public Comments: **Section 9.0**

Additionally, several appendices are included to provide supporting information to the restoration plan. These include:

Appendix A: Maps
Appendix B: Regulatory Framework and Reference Condition Approach
Appendix C: Reference Value Development and Target Justification
Appendix D: Sediment Contribution from Roads

Appendix E: Sediment Contribution from Hillslope Erosion
Appendix F: Sediment Contribution from Streambank Erosion
Appendix G: Daily TMDLs
Appendix H: Sediment and Habitat Assessment Methods and Data
Appendix I: Response to Public Comments

SECTION 2.0 STAKEHOLDER AND PUBLIC PARTICIPATION

Stakeholder and public involvement is a component of TMDL planning efforts supported by EPA guidelines and Montana State Law. This section describes State laws and policies pertaining to public participation in the Montana TMDL process and presents specific information about recent water quality restoration efforts by stakeholders within the Shields River Watershed. Development of the Shields River Watershed Water Quality Planning Framework and Sediment TMDLs has been led by DEQ in association with the Park County Conservation District (CD) and the (SVWG – previously the Upper Shields Watershed Association and the Southern Crazy Mountain Watershed Group). In addition to providing feedback during the TMDL process, the SVWG and Park County CD assisted with obtaining landowner access for data collection associated with TMDL development. Additional stakeholders involved in the TMDL development process include the U.S. Forest Service (USFS); Natural Resources Conservation Service (NRCS); Department of Natural Resources and Conservation (DNRC); and Fish, Wildlife, and Parks (FWP). Details about the stakeholder and public comment process are contained in **Section 9.0**.

2.1 State Policy

Local community and stakeholder participation and support are invaluable to the TMDL planning process. Public participation is especially important in implementing TMDLs because many plans rely heavily on voluntary cooperative approaches. The Montana WQA directs DEQ to consult with CDs and watershed groups, farmers, ranchers, environmentalists, recreationists, the Montana DNRC, the USFS, Bureau of Land Management (BLM), municipalities, and the forest, tourism and mining industries during all phases of water quality restoration planning. Because of specific considerations for each TPA, public involvement may differ with different levels of stakeholder interests.

The Montana WQA requires DEQ to administer a voluntary program of reasonable land, soil, and water conservation practices for TMDL implementation elements pertaining to nonpoint sources of pollution. Further, Montana TMDL plans must not interfere with water rights or private property rights, and do not financially obligate participants unless such measures are already a requirement under other existing Federal, State, or local regulations.

DEQ strongly believes that voluntary approaches are the most practical means of addressing the cumulative impacts of many diffuse nonpoint sources in a watershed. However, there may be exceptions for certain activities that are regulated through existing local, State, and Federal regulations. These include, but may not be limited to, streamside management zone requirements for timber harvest, minimum septic design standards and location criteria, local zoning requirements for riparian or stream bank protection, and requirements of the Montana 310 Law, which affords protection to natural stream beds and banks. Regardless of the approach, DEQ staff pledge to work with landowners, other agencies, and all stakeholders to select and implement water quality improvement measures that are compatible with local needs while achieving the attainment of water quality standards and full support of designated water uses.

2.2 Recent Restoration Projects

Management improvements have already been implemented in recent years in many parts of the watershed. The SVWG, in conjunction with the Park County CD, has helped increase awareness of water quality issues, foster watershed stewardship, and implement numerous BMPs on private land throughout the watershed (**Table 2-1**). Also, the USFS has decommissioned over 100 miles of historical logging roads and implemented several other BMPs throughout the Gallatin National Forest (GNF) in recent years, and FWP has completed several projects to improve stream habitat (**Table 2-2**). The USFS is currently prioritizing additional road improvement projects to decrease road-related sediment on several tributaries in the upper Shields River Watershed (Shuler 2007). Additionally, the USFS recently revised its Travel Management Plan (USFS 2006a) to reduce riparian habitat degradation and sediment loading to streams from roads and motorized/non-motorized trails. Although not all of the completed projects are on 303(d) listed water bodies, many issues are pervasive throughout the watershed and because impacts are cumulative, these improvements are still very beneficial to the Shields River Watershed.

Table 2-1. Recent Restoration Projects on Private Land and Activities to Promote Watershed Stewardship

Action	Purpose	Date of Action
Constructed 8 off-stream watering systems	Reduce bank erosion, habitat protection	1999-2002
Aerial assessment of upper Shields River Watershed	Assess existing conditions, for fish habitat, in particular	1999
Irrigation efficiency management workshops	Increase irrigation efficiency	2000-2001
Completed a noxious weed map and conducted noxious weed spraying	Monitor and manage spread of noxious weeds	2001
Completed 7 bank stabilization/restoration projects	Habitat restoration	2000-2006
Completed a watershed plan	Develop a comprehensive approach to watershed management	2001
Purchased soil moisture data loggers	Increase irrigation efficiency	2002
Conducted an irrigation efficiency study	Study existing conditions and options for increasing irrigation efficiency	1999-2005
Constructed off-stream watering system and riparian fencing on Chicken Creek	Reduce bank erosion, habitat protection	2006
Riparian fencing, habitat enhancement, and off-stream watering on Elk Creek and Daisy Dean Creek	Reduce bank erosion, habitat protection	In Progress
Habitat improvement and change in grazing management practices on N. Fork Horse Creek	Reduce bank erosion, habitat protection	In Progress

Table 2-2. Recent Restoration Projects Lead by the USFS and FWP

Water Body	Action	Purpose	Length Affected	Date of Action	Lead Agency
Bennett Creek	Streambank stabilization	Reduce bank erosion, habitat protection	1 mile	1995	USFS
Brackett Creek	Streambank stabilization	Habitat Restoration	0.5 miles	1999	USFS
Deep Creek	Habitat enhancement	Increase pool frequency	2 miles	1995	USFS
Deep Creek	Grazing allotment management plan revisions	Reduce riparian utilization, habitat protection	1 mile	1999	USFS
N.F. Willow Creek	Riparian protection/Streambank restoration	Habitat Restoration	1 mile	1996-1999	USFS
N.F. Willow Creek	Pool Habitat Development	Habitat Restoration	0.5 miles	1996	USFS
Shields River	Grazing allotment management plan revisions	Habitat protection, reduce sediment	1 mile	1994	USFS
Shields River	Streambank stabilization	Reduce bank erosion, habitat protection	1 mile	1995	USFS
Shields River	Moratorium on large timber sales	Habitat protection	30 miles	1993	USFS
Shields River	Bank stabilization	Stream habitat improvement	1,830 feet	1999-2000	FWP
Shields River upper watershed	Road closures and obliteration	Reduce sediment	50 miles	1993-1995	USFS
Shields River/Elk	Riparian fencing and water development	Riparian habitat protection	2.5 miles	1998	FWP

Table 2-2. Recent Restoration Projects Lead by the USFS and FWP

Water Body	Action	Purpose	Length Affected	Date of Action	Lead Agency
Creek					
Shields River	Bank stabilization and riparian fencing	Stream habitat improvement	1 mile	1999	FWP
Shields River	Bank stabilization	Stream habitat improvement	1 mile	2001	FWP
unnamed tributary to Smith Creek	Habitat enhancement	Stream habitat improvement	1 mile	2005	USFS
S.F. Shields River	Culvert and bridge replacement; Streambank stabilization	Reduce sediment, habitat protection	1 mile	2005	USFS
Shields River	Channel restoration and riparian fencing	Stream habitat improvement	1 mile	2005	FWP
Willow/Bangtail Creeks and other tributaries	Road closures and obliteration	Reduce sediment	63 miles	2006-2007	USFS
Smith Creek	~53 armored drainage dips and road improvements around 11 stream crossings	Reduce sediment	N/A	2007	USFS
Brackett/Flathead Creeks and other tributaries	Grazing allotment management plan revisions	Habitat protection, reduce sediment	1 mile	2007	USFS

SECTION 3.0
WATERSHED CHARACTERIZATION

This section describes the physical, biological, and social characteristics of the Shields River TPA. The following is a synopsis of the key factors in the basin with influence on water quality, habitat condition, and beneficial uses:

- The five major soil units consist primarily of loams although clay, cobbly, and stony textures are also present. Nearly 90% of the TPA is mapped with soils that have moderate-low susceptibility to erosion. Moderate-high susceptibility is limited to 1.4% of the TPA.
- The geology of the watershed is characterized by broad exposures of the Tertiary Fort Union Formation, composed of nonmarine mudstone, sandstone and coal. These rocks are weakly consolidated, and generally more prone to erosion than the more consolidated rocks underlying the higher elevations at the watershed margin. Quaternary alluvial, colluvial and glacial deposits are locally present throughout the watershed, and range in texture from unsorted bouldery tills to well-sorted fine-grained alluvium.
- The largest proportion of the watershed lies in private ownership, followed by USFS, Montana State lands and Bureau of Land Management (BLM).
- The watershed is mostly agricultural with primary land uses including grazing and crop production.
- Hydrology in the Shields watershed is typical of snowmelt driven systems, with peak runoff occurring in May and June. Hydrology within the watershed has been affected by a moderate to severe drought which started in 2000 and persisted until late 2005, when conditions generally started to recover.
- There is an extensive irrigation network within the watershed and demand often exceeds supply from mid-July until the end of the irrigation season (late September). Stream dewatering occurs in some tributaries and portions of the main stem Shields River, especially upstream of Wilsall.
- Although some of the riparian vegetation at lower elevations in the Shields River TPA is woody species such as cottonwood, willow, and alder, much of the woody vegetation in agricultural areas was historically removed and has been replaced by a mix of herbaceous vegetation and shrubs. At higher elevations, riparian vegetation is a mix of deciduous and coniferous trees with a shrub understory.
- The watershed contains Yellowstone cutthroat trout, a Montana species of special concern.

3.1 Physical Characteristics

3.1.1 Location and Description of the Watershed

The Shields River Watershed lies in south-central Montana, just north of Livingston and 13 miles northeast of Bozeman (**Map A-1**). The watershed encompasses 855 square miles (547,068 acres) mostly within Park County, but includes portions of Gallatin, Meagher, and Sweetgrass counties. The eastern and western boundaries of the watershed are higher elevation and

contained within the Middle Rockies level 3 ecoregion. The lower elevation areas of the watershed are contained within the Northwestern Great Plains ecoregion (**Map A-2**). The entire watershed was formerly part of the Montana Valley and Foothill Prairies ecoregion, a designation that was eliminated in 2002 and split between the Middle Rockies and Northwestern Great Plains ecoregions. However, most of the streams in the watershed are coldwater streams flowing out of the mountains, as indicated by the B-1 classification of all waterbodies in the TPA (discussed further in **Section 4.0**), resulting in different flora and fauna within the lower elevations of the watershed when compared to other aquatic communities with the Northwestern Great Plains ecoregion (Omernik 2008). The Bridger and Bangtail mountains confine the watershed to the west from which Flathead, Antelope, Brackett, Canyon, and Willow creeks flow. The Crazy Mountains form the eastern watershed boundary in which Elk, Cottonwood, Porcupine, Rock, and Daisy Dean Creeks originate. Potter and Smith Creeks flow into the Shields River from the north. The Yellowstone River flows along the southeast boundary of the watershed. The Shields River is the only major river flowing into the Yellowstone River from the north. The main stem of the Shields River is approximately 63 miles long, and its average gradient is 0.6 %, or 31 ft per mile (SCS 1983). Elevations in the watershed range from approximately 10,940 ft (3,335 m) in the Crazy Mountains to 4,380 ft (1,336 m) at the mouth of the Shields River (**Map A-3**).

3.1.2 Geology

The Shields River TPA is located at the western margin of the Crazy Mountains basin, an asymmetric bowl-like structure filled with Cretaceous and Tertiary sediments. The basin is bounded by the Bridger Range to the west, the Beartooth Range to the south, and the Pryor Range to the southeast. The Crazy Mountains Basin, therefore, is considerably more extensive than the Shields River TPA. Older, more consolidated sedimentary rocks are found along the eastern margin of the Bridger Range and beneath the basin at great depth. Early Tertiary (~50 million years ago) igneous rocks intruded the basin and form the core of the Crazy Mountains. These mountains interrupt the basin and form the eastern edge of the Shields River TPA.

Thick sequences of Tertiary, and especially Cretaceous, terrestrial, estuarine, and marine sediments fill the basin (**Map A-4**). The Cretaceous marine rocks produced economically significant amounts of hydrocarbons (oil and gas), which are generally hosted in Cretaceous clastic rocks (*e.g.* sandstone) found at depth. Hydrocarbon exploration began in the 1920s and continues to the 2000s. The Tertiary rocks, and the Fort Union Formation in particular, are noted for significant amounts of coal. The potential for coal-bed methane has attracted recent exploration to the Crazy Mountains basin and the Shields TPA.

The oldest rocks in the Shields River Watershed are Paleozoic and Mesozoic limestone, sandstone, siltstone, and shale exposed in the western portion of the watershed. These ancient rocks form the crest and eastern flank of the Bridger Mountain range from south of Brackett Creek to Flathead Creek. Various Cretaceous (140-65 million year old) shale, sandstone, mudstone, and volcanic rocks form a northeast-trending belt of rocks extending from the flanks of the Bridger Mountain range into Meagher County. These rocks fold into a series of weakly plunging anticlines and synclines in the northernmost portion of the basin, and these geologic features are visible in the basin topography. The Tertiary Fort Union Formation (65-35 million

year old) outcrops over the remainder of the TPA, including the high country of the Crazy Mountains. The Fort Union Formation consists of nonmarine shale, sandstone, mudstone, and coal. Tertiary intrusive rocks core and uplift the Crazy Mountains. Quaternary (less than 1.6 million year old) pediment gravels and glacial till cover portion of the west flank of the Crazy Mountains, and Quaternary alluvium fills much of the valley bottoms along the Shields River and its tributaries.

The geology of the Shields River Watershed has implications for water quality and quantity. The limestone exposed on the flanks of the Bridger Range is part of a karst aquifer. This type of rock has local zones of high secondary permeability, and allows for greater infiltration than a porous media aquifer (e.g. sandstone). The structure of the Bridger Range is such that much of the water in the karst aquifer passes underneath the watershed boundary and emerges on the west side of the Bridger Range, in the Gallatin River watershed. As a result, streams draining the Bridger Mountain range such as Brackett and Flathead creeks have lower flows than would be expected from drainage areas this size.

The rocks exposed in the watershed are generally weakly consolidated and more prone to erosion than the harder rocks at the watershed margins. This difference in erodibility is the primary factor controlling the watershed morphology. The Cretaceous and Tertiary rocks are also prone to development of saline seep due to naturally-occurring salts in the sediments and soils derived from them.

3.1.3 Soils

Soils data for the Shields River planning area are available through the NRCS state soil geographic database (STATSGO), which provides a method for consistent assessments of generalized soil characteristics for medium-scale studies. The Shields River Watershed has 27 soil units with five types comprising 57% of the watershed (**Table 3-1, Map A-5**). The five major soil units consist primarily of loams although clay, cobbly, and stony textures are also present. Approximately 7% of the watershed contains unweathered bedrock outcrop. Collectively, the soil units making up the Shields River Watershed are well drained and not hydric or likely to develop wetlands and are not classified as prime farmland. Almost all soil units have an estimated six foot depth to water table.

Table 3-1. Percentages of Major Soil Units in the Shields River Watershed

Map Unit Name	Percent Area	Surface Texture
Castner-Chama-Regent (Mt113)	12.8%	Loam
Castner-Savage-Chama (Mt112)	12.7%	Clay
Savage-Work-Chama (Mt522)	12.4%	Cobbly Clay Loam
Castner-Regent-Big Timber (Mt118)	11.7%	Stony Loam
Garlet-Cowood-Rock Outcrop (Mt213)	7.0%	Unweathered Bedrock

The USGS Water Resources Division (Schwartz and Alexander, 1995) created a dataset of hydrology-relevant soil attributes, based on the STATSGO soil database. The STATSGO data is intended for small-scale (watershed or larger) mapping and is too general to be used at scales larger than 1:250,000. It is important to realize, therefore, that each soil unit in the STATSGO data may include up to 21 soil components. Soil analysis at a larger scale should use NRCS Soil

Survey Geographic (SSURGO) data. The soil attributes considered in this characterization are erodibility and slope.

Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier & Smith 1978). K-factor values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Susceptibility to erosion is mapped on **Map A-6**, with soil units assigned to the following standard ranges: low (0.0-0.2), moderate-low (0.2-0.29) and moderate-high (0.3-0.4). Values of >0.4 are considered highly susceptible to erosion. No values greater than 0.33 are mapped in the Shields TPA. Nearly 90% of the TPA is mapped with soils that have moderate-low susceptibility to erosion. Moderate-high susceptibility is limited to 1.4% of the TPA.

Slope varies widely across the TPA (**Map A-7**). Slopes over 50° are mapped on the flank of the Bridger Range, at the western edge of the watershed. The most common slope ranges are 10°-20°, mapped over 37% of the TPA, and 30°-40°, accounting for 29% of the TPA. Very low slopes (1°-2°) are mapped along the floodplains of the Shields River and Potter Creek. As these slopes are averages for soil units mapped at a scale of 1:250,000, slopes are much more variable at a larger scale, particularly in dissected uplands and mountains. Slope analysis at a finer scale, using a USGS 1-arc second digital elevation model (DEM), reveals that the mean slope across the TPA is 8°, and more than half the TPA is characterized by slopes less than 10°.

3.1.4 Hydrology

The Shields River Watershed has one active USGS stream gage which lies on the lower main stem of the Shields River near Livingston (**Map A-8**). This gage has been operational since 1979 and has recorded mean daily stream flows for the past 25 years with the exception of the 2002 water year. Supplemental historic flow records are available from two gages that are no longer operational, including one near Wilsall (#6193000) and one near Clyde Park (#6193500) (**Table 3-2, Map A-8**). The Wilsall gage was operational between 1935 and 1957, and the Clyde Park gage has discontinuous stream flow records from 1921-1967. Between 1967 and 1979, no USGS gaging stations were operational in the Shields River Watershed. Hydrologic data for the basin are therefore spatially limited, and the available USGS dataset includes a 12-year long gap in stream flow records between 1967 and 1979.

Table 3-2. USGS Gaging Stations in the Shields River Watershed

USGS Gage Number	Gage Name	Drainage Area (sq mi)	Period of Record	Flood of Record
USGS 6193000 discontinued	Shields River near Wilsall	88	1935-1957	1770 cfs (1948)
USGS 6193500 discontinued	Shields River at Clyde Park	544	1921-1967 (discontinuous)	4500 cfs (1948)
USGS 6195600 active	Shields River at Livingston	852	1978-present (missing WY 2002)	5600 cfs (1979)

Stream flow patterns within the Shields River basin reflect typical snowmelt runoff cycles of the region. Stream flows typically begin to rise in April, and mean monthly discharges tend to peak in May or June. Mean monthly May/June flows are typically about 750-850 cfs at Livingston, 500 cfs at Clyde Park, and 250 cfs at Wilsall. Although the largest flows occurred at the mouth

of the river near Livingston, water yield per square mile is much higher at the Wilsall gage, reflecting the importance of snowmelt runoff to overall basin water yield (**Figure 3-1**). The lowest recorded 7-day minimum flow values at each gage indicate that, at Livingston, average 7-day low flows have exceeded 20 cfs for the entire period of record at that gage. Further upstream, minimum recorded 7-day flows at Clyde Park and Wilsall are less than 10 cfs (**Figure 3-1**).

Numerous major flood events have occurred within the Shields River Watershed. The largest flood recorded on the Shields River occurred in 1948 when measured flows at Clyde Park were 4,500 cfs (**Figure 3-2**). The estimated return interval for this event is 50-75 years (NRCS 1998). Twenty five-year flood events occurred in 1943, 1979, 1981, 1992, and 1996 (NRCS 1998). A major flood event also occurred in the watershed in 1975, and, although this event occurred during the gap in flow records, a measured peak discharge is not available. Climate records indicate that in 1975 over 8 inches of precipitation fell at Wilsall during May and June (NOAA climate station Wilsall 8 ENE #249023). The 1975 flood apparently had a major influence on the Shields River channel morphology as local residents have indicated that the modern geomorphic character of the Shields River reflects the effects of that event (Inter-Fluve 2001).

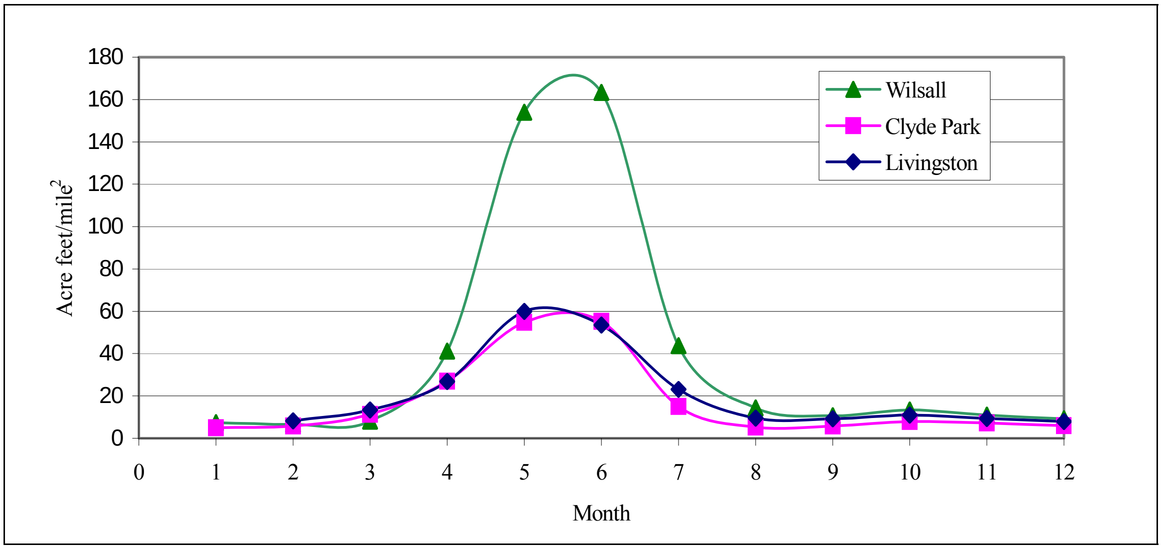

Figure 3-1. Peak Flows Measured at Shields River Gaging Stations for Periods of Record

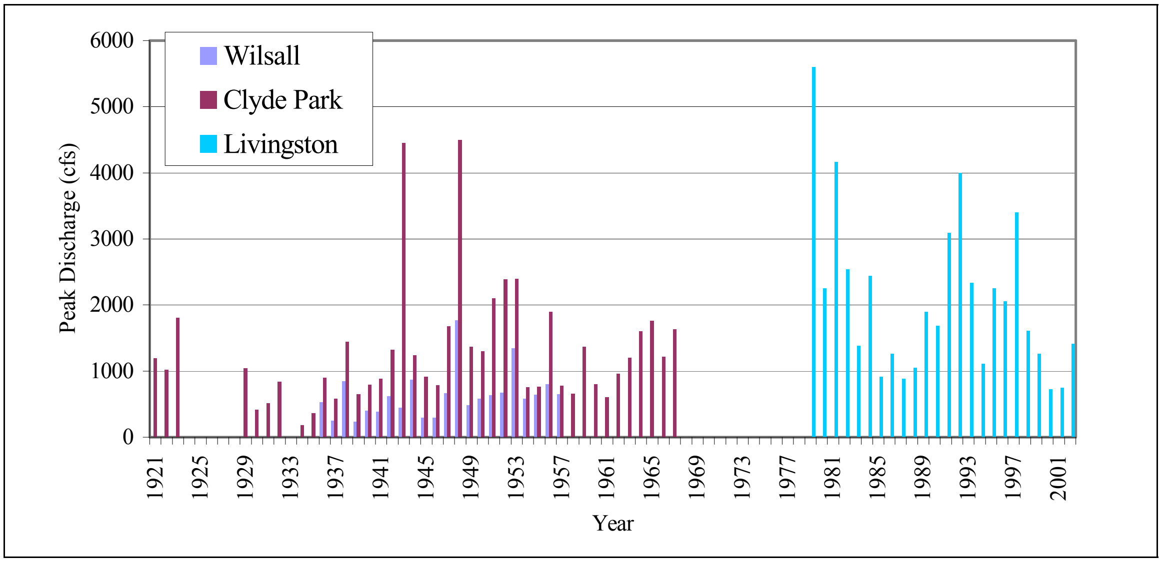

Figure 3-2. Mean Monthly Water Yield for Gaging Stations on the Shields River

3.1.5 Climate

Within the Shields River TPA, the National Oceanographic and Atmospheric Administration (NOAA) operates one climate station (Wilsall 8ENE) and the NRCS operates four Snowpack Telemetry (SNOTEL) stations (Brackett Creek, Sacajawea, Porcupine and S. Fork Shields) (**Map A-8**). There is a decommissioned NOAA climate station at Wilsall that operated from 1950-1969. The current station has been in operation since 1957 and is located at an elevation of 5,840 feet.

May and June are typically the wettest months. NOAA climate data indicate the average total precipitation is 20.3 inches per year with 99.2 inches total snowfall. However, precipitation and temperature within the watershed vary with elevation, which ranges from approximately 10,940 to 4,380 feet. According to Oregon State University's PRISM data (PRISM 2004), average annual precipitation ranges from 15 to 53 inches in the Shields River TPA. Precipitation in the valley is generally less than 20 inches, but is greater than 40 inches in the Bridger and Crazy Mountains (**Map A-6**). NOAA data include monthly snowfall, precipitation, maximum temperatures, and minimum temperatures (**Table 3-3**). January is typically the coldest month with an average temperature of 22.8 °F and July is typically the hottest month with an average temperature of 61.6 °F. The watershed has generally been recovering for the past couple of years from severe drought conditions that started in 2000 and persisted to late 2005 (NRIS, 2007).

Table 3-3. Monthly and Annual Climate Summary from NOAA Station Wilsall 8ENE for the Period of Record from April 1957 through September 2007

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max Temp (F)	33.4	36.7	42.2	50.8	60.8	69.6	79.0	78.4	67.2	55.9	41.2	34.4	54.1
Average Min. Temp. (F)	12.1	14.6	19.0	26.2	34.1	41.1	46.0	44.8	37.5	30.0	20.3	14.0	28.3
Average Total Precip. (in.)	0.9	0.7	1.4	1.9	3.2	3.4	1.8	1.7	1.8	1.5	1.0	0.9	20.3
Average Snowfall (in.)	15.8	12.9	18.1	13.3	5.8	0.4	0.0	0.0	2.1	4.9	10.3	14.4	99.2

3.2 Social Characteristics

According to the 2000 census, the Shields River Watershed has a population of over 1,900 people. Two small towns, Wilsall and Clyde Park, contain 237 and 310 people, respectively. The watershed is primarily rural farms and ranches ranging in size from less than 50 acres to over 1,000 acres. The primary agricultural products in the valley are beef, hay, and grain production, including wheat, barley, and oats. According to an NRCS general resource assessment (NRCS 1998), the average cattle herd size (cows and calves) in the watershed is greater than 200 head.

3.2.1 Land Ownership

Private land comprises the majority of the Shields River Watershed at over 80% (**Map A-9**). Of the remaining 19% land ownership, the USFS manages 16.5%, 2.6% is State lands, and the BLM manages less than 1% (**Table 3-4**). Some of the USFS lands represent private lands acquired in

the 1990s, including the purchase of over 90,000 acres of private inholdings under the Gallatin Land Consolidation Act of 1993 and 1998 (USFS, 2004).

Table 3-4. Land Ownership in the Shields River Watershed

Land Ownership	**Percent of Watershed Area**
Private Land	80.9%
US Forest Service	16.5%
Montana State Trust Lands	2.6%
US Bureau of Land Management	<1%

3.2.2 Land Use

Land use in the Shields River Watershed is typical of a south-central Montana rural, agrarian valley with almost 75% of the area used for farming or ranching (**Map A-10, Table 3-5**). Based on the USGS national land cover database (NLCD), the most prevalent cover type in the Shields River Watershed is grass rangeland (56.8%), followed by coniferous and deciduous forest (23.0%). Developed lands, including residential areas, account for less than 0.1% of the watershed. Almost a third of the population in the watershed lives in Wilsall and Clyde Park. Although land is more commonly being subdivided, most other residents of the watershed live on widely spaced ranches. Although much of the USFS land cover is evergreen forest, most timber harvest occurred historically (on public or previously private land), and land use within GNF is shifting to recreational use (USFS 2006a; USFS 2006b). Recreational uses include off-road vehicles, horseback riding, fishing, hunting, hiking, and camping. Some timber harvesting has and will continue to occur on private land (USFS 2006a; USFS 2007). A very small amount of historic mining for calcite has occurred within the watershed.

Table 3-5. Land Use in the Shields River Watershed

Land Use/Coverage	**Percent Area**
Grass Rangeland	56.8%
Coniferous and Deciduous Forest	23.0%
Crop/Pasture	14.1%
Brush Rangeland	2.7%
Timber Harvest	<1%
Developed	<1%
Other Agriculture	<1%

3.2.2.1 Irrigation

Irrigation of agricultural lands in the Shields River Valley constitutes a primary use of surface water in the region. The main surface water diversions occur on Cottonwood Creek (upper Cottonwood system), Flathead Creek (Shields Canal Company ditch), and on the main stem Shields River (lower Shields River Canal Company ditch, and Shields River Ranch ditch). Big Ditch is the largest canal in the upper watershed, supplying water to approximately 2,200 irrigated acres. Much of the area irrigated by Big Ditch is located on the Jordan Bench, which is approximately 150 feet above the Shields River Valley (Dolan 2001). Big Ditch feeds a system of smaller ditches, including Meyers Ditch, and Jordon Reservoir which can store approximately 900 acre-feet of water for late season releases. Approximately 40,000 acres of land are irrigated throughout the watershed, 72% with flood irrigation and 28% with sprinkler irrigation (NRCS

1998). Between both methods, the overall irrigation efficiency for the watershed is an estimated 40%.

Irrigation water deficiencies are common in late July and August in the Shields River Valley. Pre-1900 water rights appropriations total 493.4 cfs on the Shields River (NRCS 1998), and these appropriations have the potential to exceed available supply, depending on the timing of flow diversions. Stream dewatering has occurred in some tributaries and reaches of the main stem Shields River, especially upstream of Wilsall (Inter-Fluve 2001; Dolan 2005). Periods of dewatering in portions of the upper Shields River were observed every summer from 2000-2004 (Dolan 2005). Limited flow and dewatering in this part of the river results from a combination of the Big Ditch and other smaller diversions. The Shields River gradually picks up more return flows as it heads downstream towards Wilsall (Dolan 2008). In an effort to optimize stream flows for fish, wildlife, and agricultural users in the basin, an evaluation was performed in 1999-2000 to assess relationships between water supply, water demands, and irrigation system efficiencies (Dolan 2005). Results from that analysis showed that for a median flow year, the water supply of the upper Shields River is probably only sufficient to meet current demands until about mid-July. The shortage in water supply for irrigation needs has prompted consideration of several water management alternatives, including increased irrigation efficiency, more extensive flow measuring devices, and increased reservoir storage (Dolan 2005, Compston 2002).

3.3 Ecological Characteristics

3.3.1 Vegetation

As evidenced in its land use, crops and grassland/shrub land range comprise the majority of the watershed (**Table 3-6, Map A-11**) (Wildlife Spatial Analysis Lab, 1998). The second largest vegetation class is coniferous and deciduous forests (23%) including lodgepole pines, Douglas firs, and mixed mesic and subalpine forest species. Native vegetation in the Shields River Valley is consistent with elevation-based gradients in mountain valleys of the northern Rocky Mountains. As elevation increases, the vegetation turns to mesic and xeric shrub lands dominated by sagebrush, transitions to grasslands and, eventually, culminates in coniferous forests characterizing the second largest vegetation class type.

Table 3-6. Percentages of Major Vegetation Cover Types in the Shields River Watershed

Vegetation Cover Type	Percent Area
Agricultural (crops)	10.19%
Coniferous and Deciduous Forest	23.45%
Grasslands	36.90%
Mesic and Xeric Shrubs	11.40%
Riparian	7.45%
Rock, Badlands, Snow or Ice	10.49%
Urban	<1%
Water	<1%

Although some of the riparian vegetation at lower elevations in the Shields River TPA is woody species such as cottonwood, willow, and alder, much of the woody vegetation in agricultural areas (**Map A-11**) was historically removed and has been replaced by a mix of herbaceous

vegetation and shrubs (Inter-Fluve, 2001). At higher elevations, riparian vegetation is a mix of deciduous and coniferous trees with a shrub understory.

Invasive weeds are a growing concern in the Shields River TPA. Priority species include Russian and spotted knapweed (*Acroptilon repens* and *Centaurea maculosa*, respectively), leafy spurge (*Euphorbia esula*), Dalmation toadflax (*Linaria vulgaris*), and whitetop (*Cardaria* sp.) (NRCS 1998). The Montana Noxious Weed Trust Fund has identified Russian and spotted knapweeds, Dalmatian toadflax, leafy spurge, and sulfur cinquefoil as weeds the Montana noxious weed survey and mapping system must monitor on a section basis (Montana Noxious Weed Trust Fund 1998). The Park County Extension Office and Park County Weed Board have been active in public education for noxious weeds and have sprayers available for free for public use (Park County Extension 2007). The Park County Weed Board has a weed plan that is updated annually, requires new subdivisions to develop a weed management plan, and encourages landowners to use biocontrol or large animal grazing. Also, the SVWG developed a noxious weed map in 2001 that it is in the process of updating (SVWG 2008).

Fire activity has been limited in recent decades. The USFS Region 1 office and the USFS remote sensing applications center provides data on fire locations from 1940 to the present (**Map A-12**). Three fires are mapped in the TPA, ranging from 374 to 1,385 acres. The largest fire occurred in the southern Castle Mountains in 1994 and is unnamed. This fire straddled the watershed boundary between the TPA and the Musselshell basin with just under 50% of the burned area inside the Shields River TPA. The other fires were both in the western Crazy Mountains. The Sugarloaf fire (2000) burned 374 acres and the Slippery Rock fire (2003) burned 1,078 acres. Two small fires burned briefly in 2006, one north of Clyde Park and one near Highway 86 in the upper reaches of Flathead Creek.

3.3.2 Fisheries

The Shields River Watershed supports eleven species among four families of fishes (**Table 3-7**). Native salmonids are the Yellowstone cutthroat trout and mountain whitefish. The basin also supports three introduced salmonids, brook trout, rainbow trout, and brown trout. Two species of cyprinids or members of the minnow family present in the Shields River Watershed are lake chub and longnose dace. Three species of catostomid or sucker occur in the watershed including mountain sucker, white sucker, and longnose sucker. The mottled sculpin is the sole member of its family in the watershed. No stocking has occurred in the watershed since the early 1970s (Shepard 2004).

Table 3-7. Fishes Present in the Shields River Watershed

Family/Common Name	Scientific Name	Introduced/Native
Salmonidae		
Yellowstone cutthroat trout	*Oncorhynchus clarki bouvieri*	Native
Yellowstone cutthroat trout ×rainbow trout hybrid	*O. clarki bouvieri ×O. mykiss*	
Brook trout	*Salvelinus fontinalis*	Introduced
Rainbow trout	*O. mykiss*	Introduced
Brown trout	*Salmo trutta*	Introduced
Mountain whitefish	*Prosopium williamsoni*	Native
Cyprinidae		
Lake chub	*Cousieus plumbeus*	Native

Longnose dace	*Rhinichthys cataractae*	Native
Catostomidae		
Mountain sucker	*Catostomus platyrhynchus*	Native
White sucker	*Catostomus commersoni*	Native
Longnose sucker	*Catostomus catostomus*	Native
Cottidae		
Mottled sculpin	*Cottus bairdi*	Native

Yellowstone cutthroat trout (YCT) is considered a sensitive species by Region 1 of the USFS and a Species of Special Concern by the State of Montana. A recent status assessment for Yellowstone cutthroat trout concluded that the watershed has 453 miles of habitat; 277 miles are also inhabitated by non-native species and 176 miles have native fish species only (May et al. 2007). The total available habitat for Yellowstone cutthroat trout roughly corresponds to the ownership breakdown of the watershed with 77% of habitat being on private land, 21% being on USFS land, and 2% being on State land (May et al. 2007). This proportion of historically occupied habitat still supporting YCT is the greatest among 4th order hydrologic units in Montana, making the Shields River watershed a stronghold for the species (Endicott 2008). A growing concern in the Shields River watershed is whirling disease; YCT are highly susceptible to it, and sediment loading and organic enrichment are factors that influence the abundance of *Tubifex tubifex*, the intermediate host for whirling disease (Endicott 2008).

SECTION 4.0
APPLICATION OF MONTANA'S WATER QUALITY STANDARDS FOR TMDL DEVELOPMENT

This section and **Appendix B** present details about TMDL development requirements, applicable Montana water quality standards, and a general description of how narrative standards are interpreted and applied to assess water quality and set targets.

4.1 TMDL Development Requirements

Section 303 of the Federal CWA and the Montana WQA (Section 75-5-703) requires development of TMDLs for impaired water bodies that do not meet Montana water quality standards. Although water bodies can become impaired from pollution (e.g. flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, and metals), the CWA and Montana State Law (75-5-703) both require TMDL development for waters impaired only by pollutants. Section 303 also requires states to submit a list of impaired water bodies to the EPA every two years. Prior to 2004, the EPA and the Montana DEQ referred to this list as the 303(d) List.

Since 2004, the EPA has requested that states combine the 303(d) List with the 305(b) Report containing an assessment of Montana's water quality and its water quality programs. The EPA refers to this new combined 303(d)/305(b) Report as the Integrated Water Quality Report. The 303(d) List also includes identification of the probable cause(s) of the water quality impairment problems (e.g. pollutants such as metals, nutrients, sediment or temperature) and the suspected source(s) of the pollutants of concern (e.g. various land use activities). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each water body is used for consistency; the actual methodology is identified in DEQ's Water Quality Assessment Process and Methods (DEQ 2006b). This methodology was developed via a public process and was incorporated into the EPA-approved 2000 version of the 305(b) Report (now also referred to as the Integrated Report).

Under Montana State Law, an "impaired water body" is defined as a water body or stream segment for which sufficient credible data show that the water body or stream segment is failing to achieve compliance with applicable water quality standards (Montana WQA; Section 75-5-103(11)). State Law and Section 303 of the CWA require states to develop all necessary TMDLs for impaired or threatened water bodies. There are no threatened water bodies within the Shields TPA.

A TMDL is a pollutant budget for a water body identifying the maximum amount of the pollutant that a water body can assimilate without causing applicable water quality standards to be exceeded. TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources, in addition to natural background sources, and must incorporate a MOS and consider influences of seasonality on analysis and compliance with water quality standards.

To satisfy the Federal CWA and Montana State Law, TMDLs will be developed for each water body-pollutant combination identified on Montana's 303(d) List of impaired or threatened waters in the Shields River TPA. State Law (Administrative Rules of Montana (ARM) 75-5-703(8)) also directs Montana DEQ to "...support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for water bodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or local regulations.

4.2 Applicable Water Quality Standards

Water quality standards include the uses designated for a water body, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the existing high quality of a water body. The ultimate goal of this TMDL plan, once implemented, is to ensure that all sediment-related water quality standards are met for streams identified on Montana's 303(d) List. Water quality standards form the basis for the water quality targets described in **Appendix C**.

4.2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a water body based on the potential of the water body to support those uses. Designated Uses or Beneficial Uses are simple narrative descriptions of water quality expectations or water quality goals. There are a variety of "uses" of state waters including growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana WQA directs the Board of Environmental Review (BER, i.e., the State) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses ARM 17.30.607-616 and to adopt standards to protect those uses (ARM 17.30.620-670). **Appendix B** provides additional detail on water body classification and beneficial uses under Montana Law.

All water bodies within the Shields River Watershed are classified as B-1. The Montana B-1 classification states that, "Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply," (ARM 17.30.623(1)). On the 2006 303(d) List, six streams encompassing seven stream segments failed to support all of their beneficial uses (**Table 4-1; Map A-13**). The upper segments of Cottonwood and Rock Creeks were fully supporting all beneficial uses. All other stream segments were either fully supporting or not assessed for agricultural and drinking water uses, and partially supporting aquatic life, coldwater fishery, and (primary) contact recreation uses.

Table 4-1. 2006 Beneficial Use Status for 303(d) Listed Streams in the Shields River Watershed
Streams in shaded cells are not meeting uses because of pollution-related causes.

Stream Name	Water Body ID	Listing Year	Beneficial Use Support					
			Agriculture	Aquatic Life	Coldwater Fishery	Drinking Water	Industry	Contact Recreation
Antelope Creek	MT43A002_020	2006	F	P	P	F	F	P
Cottonwood Creek	MT43A002_031	2006	F	P	P	F	F	P
	MT43A002_032	2006	F	F	F	F	F	F
Elk Creek	MT43A002_040	2006	X	P	P	X	X	P
Potter Creek	MT43A002_010	2006	F	P	P	F	F	F
Rock Creek	MT43A002_051	2006	F	P	P	F	F	P
	MT43A002_052	2006	F	F	F	F	F	F
Shields River	MT43A001_011	2006	X	P	P	X	X	P
	MT43A001_012	2006	X	P	P	X	X	P

F = Fully Supporting; P = Partially Supporting; X = Not Assessed (Lacking Sufficient Credible Data)

4.2.2 Standards

In addition to the Use Classifications described above, Montana's water quality standards include numeric and narrative criteria as well as a nondegradation policy. **Section B.2.2** in **Appendix B** provides details on these standards, with narrative standards being applicable to the Shields River TPA sediment-related impairment causes. These narrative standards include the beneficial use support standard (17.30.623[1]) for a B-1 stream, and the standards in **Table B-2** that can be applied to excess sediment concentrations in the Shields River and Potter Creek.

Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative standards identified in **Appendix B** (**Table B-2**). The narrative criteria do not allow for harmful or other undesirable conditions related to either (a) increases above naturally occurring levels of sediment or (b) municipal, industrial, and agricultural discharges to state surface waters. This is interpreted to mean that water quality goals should strive toward a reference condition that reflects a water body's greatest potential for water quality given current and historic land use activities where all reasonable land, soil, and water conservation practices have been applied and resulting conditions are not harmful, detrimental, or injurious to beneficial uses. As discussed in **Section B.1.2**, reasonable land, soil, and water conservation practices generally include best management practices (BMPs), but additional conservation practices may be required to achieve compliance with water quality standards and restore beneficial uses.

4.3 Developing Water Quality Targets

Quantitative water quality targets and supplemental indicators are developed to help define the problem and help determine successful TMDL implementation. This document outlines water quality targets for sediment in the Shields River TPA. TMDL water quality targets help translate the applicable numeric or narrative water quality standards for the pollutant of concern. For

pollutants with established numeric water quality standards, the numeric values are used as TMDL water quality targets. For pollutants with only narrative standards, the water quality targets help to further interpret the narrative standard and provide an improved understanding of impairment conditions. In the Shields River TPA, sediment has narrative standards and will require the selection of appropriate TMDL water quality targets and supplemental indicators (discussed in detail in **Section 5.0**). Specific values for targets and supplemental indicators are determined from the most applicable reference condition approach(es).

4.3.1 Defining Reference Conditions

DEQ uses the reference condition to evaluate compliance with many of the narrative water quality standards. The term "reference condition" is defined as the condition of a water body capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a water body's greatest potential for water quality given existing and historic land use activities.

When possible, reference sites are used to determine the difference between a potentially impacted area and a "natural" or least impacted water body. Reference sites may include a similar water body within the region, a nearby watershed, or a least impacted section of the stream of interest. Historical data can also provide useful reference site information for an impaired stream reach if the historical data is from a period that precedes impairment causing activities. Water bodies used to determine reference condition are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. Because the intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity, reference conditions should reflect minimum impacts from human activities.

The preferred approach for determining reference condition is the use of regional, internal, or historical reference data, but when appropriate reference data are sparse or non-existent, secondary reference approaches can be applied. These secondary approaches include modeling, literature reviews, and professional judgment. In many situations, a combination of reference site and secondary reference approaches are used to establish reference conditions. The DEQ approach to determining reference conditions and using reference sites for the Shields River system is included in **Appendix C** and DEQ's Water Quality Assessment Process and Methods (DEQ 2006b).

4.3.2 Water Quality Target Development

Since there is no single parameter that can be applied to provide a direct measure of beneficial use support associated with sediment, a suite of water quality targets and supplemental indicators have been selected to be used in combination with one another. The water quality targets are considered to be the most reliable and robust measures of the pollutant. Supplemental indicators are typically not sufficiently reliable to be used alone as a measure of support. These are used as supplemental information, in combination with the water quality targets, to better define potential problems caused by a pollutant.

By being related to both the pollutant of concern and the most sensitive beneficial use(s), water quality targets provide a quantitative way to assess beneficial use support and they provide a link between the pollutant of concern and the suspected impaired beneficial use. Reference data are used for target development to establish a threshold value representing “naturally occurring” conditions where all reasonable land, soil, and water conservation practices are in place. The comparison of existing data to water quality targets (based on sufficient data) can either support the water quality impairment listings on the 303(d) list and aid in TMDL development or help identify the need for additional data collection. Water quality targets also serve as goals by which to measure the progress of future restoration efforts.

SECTION 5.0
EXISTING CONDITION AND COMPARISON TO WATER QUALITY TARGETS

The following sections provide a summary of available data and water quality targets for the Shields River, Antelope Creek, and Potter Creek. Although placement onto the 303(d) list indicates impaired water quality, a comparison of water quality targets to existing data helps define the level of impairment and helps guide the development of TMDL allocations. It also establishes a starting point from which to measure future water quality restoration success.

5.1 Water Bodies and Pollutants of Concern

As mentioned in **Section 1.0**, as required by federal court order, DEQ must address all pollutant/water body combinations appearing on the 1996 303(d) List that are still listed as impaired on the 2006 303(d) List by 2012. The focus of this document is sediment-related impairments; these impairments relate to excessive sediment deposited on stream bottoms and in the water column. There are three water bodies within the Shields River TPA that have sediment-related listings on the 1996 and 2006 303(d) Lists: Shields River, Potter Creek, and Antelope Creek. Although the Shields River was broken out into two stream segments between 1996 and 2006, both segments are listed for sediment-related impairments on the 2006 List. The specific sediment-related listing causes of impairment in the Shields River Watershed include sedimentation, siltation, solids (suspended/bedload), habitat alterations, and alterations in streamside or littoral vegetative cover (**Table 5-1**). Data collected to assist with TMDL development suggest the Antelope Creek listing is actually from suspended organic matter related to excess nutrient loading, and a TMDL has not been prepared at this time. The impairment cause will probably be addressed during future development of nutrient-related TMDLs within the Shields River TPA.

Table 5-1. Probable Sediment Sources for 303(d) Listed Water Bodies

303(d) Listed Water Body	List	Probable Cause(s)	Probable Source(s)
Antelope Creek MT43002_020	2006	Solids (suspended/bedload)	Agriculture, Livestock, Source unknown
	1996	Suspended solids	Agriculture, Natural sources, Range land
Potter Creek MT43A002_010	2006	Sedimentation/siltation, Solids (suspended/bedload)	Impacts from Hydrostructure flow regulation/modification
	1996	Siltation, Suspended solids	Agriculture, Natural sources, Range land, Silviculture
Shields River (upper) MT43A001_012	2006	Sedimentation/siltation, Physical substrate habitat alteration, Alteration in streamside littoral vegetative cover	Riparian grazing, Silviculture, Streambank modification/destabilization
	1996	Other habitat alterations, Siltation, Suspended solids	Agriculture, Highway/road/bridge construction, Irrigated crop production, Land development, Natural resources, Range land, Silviculture, Stream bank modification/destabilization
Shields River (lower)	2006	Sedimentation/siltation, Physical substrate habitat	Agriculture, Bank modification/destabilization

MT43A001_011		alteration, Alteration in streamside littoral vegetative cover	
	1996	Other habitat alterations, Siltation, Suspended solids	Agriculture, Highway/road/bridge construction, Irrigated crop production, Land development, Natural resources, Range land, Silviculture, Stream bank modification/destabilization

5.1.1. Effects of Sediment on Aquatic Life and Coldwater Fisheries

Erosion and sediment transport and deposition are natural functions of stream channels. Sediment deposition is needed to build streambanks and floodplains. Regular flooding allows sediment deposition to build floodplain soils and prevents excess scour of the stream channel. Riparian vegetation and natural instream barriers such as large woody debris (LWD), beaver dams, or overhanging vegetation help trap sediment and build channel and floodplain features. When these barriers are absent or excessive erosion takes place due to altered channel morphology or riparian vegetation, excess sediment is transported through the channel. The excess sediment may be deposited in critical aquatic habitat areas not naturally characterized by high levels of fine sediment, or a combination of coarse and fine sediment can accumulate in pools and decrease available habitat.

Excess sediment often has detrimental effects on various aspects of aquatic life within streams. For instance, elevated suspended sediment levels reduce light penetration, which may cause a decline in primary production. As a result, aquatic invertebrate communities may also decline, which may trigger a decline in fish populations. Deposited particles may obscure sources of food, habitat, hiding places, and nesting sites for invertebrates and fish.

Excess sediment may also impair biological processes of individual aquatic organisms. When present in high levels, sediment may clog the gills of fish and cause other abrasive damage. Abrasion of gill tissues triggers excess mucous secretion, decreased resistance to disease, and a reduction or complete cessation of feeding (Wilber 1983; McCabe and Sandretto, 1985; Newcombe and MacDonald 1991). High levels of benthic fine sediment can also impair reproductive success of fish. In addition to decreasing the availability of spawning sites, an accumulation of benthic fine sediment reduces the flow of water through gravels harboring salmonid eggs, depleting oxygen supply to embryos, and causing metabolic wastes to accumulate around embryos, resulting in higher mortality rates (Armour et al., 1991). This accumulation of fine sediment also can also prevent the emergence of a significant percentage of newly hatched fish.

5.2 Inventory and Summary of Pollutant Sources

All streams have a sediment load that is associated with natural sources such as landslides, wildlife grazing, channel migration, flooding, and natural upland erosion. Flooding, in particular, has been a prominent natural source of erosion within the Shields River Watershed (NRCS 1998). Sediment production can easily be increased and/or depositional processes altered because of human activities that reduce vegetation or increase runoff such as grazing, roads,

silviculture, urban development, crop production, or other activities. For flood events, for example, human activities can lead to significant negative impacts such as increased runoff rates, increased streamflow velocities, increased upland and streambank erosion, and a constricted floodplain. More generally, sediment is delivered to streams from upland/hillslope erosion, roads, streambank erosion, and direct disturbance of the stream bottom.

Because there are no point sources requiring discharge permits within the Shields River Watershed, all human-related sources of sediment are categorized as nonpoint sources, originating from various land uses. As discussed in **Section 3.2.2**, the watershed is primarily agricultural with land cover being a mix of rangeland, cropland, and forest. Historically, logging practices and associated road construction in the upper watershed increased water and sediment yields, but practices changed in the early 1990s and vegetation has stabilized soils and water yield (Shuler 2007). Historical removal and continued degradation of riparian vegetation is widespread throughout the watershed (NRCS 1998). This can cause problems by lessening the watershed's ability to filter out sediment and other pollutants transported from upland sources and also by weakening streambank stability. The primary source categories within the Shields River Watershed include unpaved roads, streambank erosion, and hillslope erosion. Mechanisms for sediment loading include natural erosion, improperly maintained roads, channel manipulation, removal of riparian vegetation, bank trampling, overgrazing of riparian vegetation, and flow manipulation.

As discussed in **Section 3.2.2.1**, flow alterations from water diversions and irrigated agriculture are prominent in the Shields River Watershed. During several recent summers, demand exceeded supply from mid-July through late September, and dewatering has been observed in several tributaries and portions of the Shields River (Dolan 2005). Below a certain threshold, water loss can be detrimental to aquatic life and also to a stream's ability to transport sediment. Although irrigation return flows add water back to stream systems, if surface water returns contain excess sediment and other pollutants, they can degrade the quality of the receiving water body.

5.3 Pollutant Transport and Seasonality

All TMDL/Water Quality Planning Framework documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), and LAs. Sediment loading varies considerably with season. For example, delivery increases during spring months when snowmelt delivers sediment from upland sources and resulting higher flows scour streambanks. However, these higher flows also scour fines from streambeds and sort sediment sizes, resulting in a temporary decrease in the proportions of deposited fines in critical areas for fish spawning and insect growth. The ability of a water body to transport sediment and flush deposited fine sediment can be lessened by factors such as altered channel form (e.g. an overwidened channel) and hydrologic. Because both fall and spring spawning salmonids reside in the Shields TPA, streambed conditions need to support spawning through all seasons. Therefore, sediment targets are not set for a particular season and source characterization is geared toward identifying average annual loads.

The sediment conditions of concern in the Shields River Watershed are (1) sedimentation and (2) stream channel instability that affects sediment transport. Sediment delivery to the stream

network is periodic and highly dependent upon weather conditions. Increased sediment loading during runoff events from nonpoint sources have a slow, cumulative influence on sedimentation in fish spawning areas. Likewise, sediments will flush out of spawning areas gradually after implementation of restoration practices. The stream channel's stability is also a slowly changing, long-term condition which can affect sediment transport and instream sediment sorting. Unless catastrophic flooding occurs, sedimentation and stream channel stability conditions do not fluctuate a great extent over a year's timeframe in the Shields River Watershed. Sediments (sand) that impact beneficial uses move through the stream network slowly and therefore an average annual timeframe for TMDLs is appropriate for the Shields River Watershed.

5.4 Water Quality Standards Target Development

The water quality targets presented in this section are based on the best available science and information available at the time this document was written. TMDL targets are not stagnant components of this plan. Targets will be assessed during future TMDL reviews for their validity when new information may provide a better understanding of reference conditions.

Since natural variability in streams is high, detecting departures from the "naturally occurring" condition is often very difficult. In most stream systems it is not possible to rely on any single indicator to define the extent of the sediment problem. Thus, a suite of water quality targets and supplemental indictors will be used to assess sediment impacts in the Shields River Watershed. The sediment targets try to address the following questions:

1. Are there fish/aquatic life data that suggests an impact from sediment?
2. Have anthropogenic sources increased sediment erosion and/or delivery?
3. Is there a sediment supply problem (i.e., too much or too little sediment)?
4. Is there an indication of an in-channel sediment transport problem?

The first question is often difficult to answer without answering the other three questions, which is the reason target (and supplemental indicator) development often focuses on Questions 2 through 4.

5.4.1 Sediment Water Quality Targets and Supplemental Indicators

For the Shields River TPA, a suite of water quality targets and supplemental indicators are presented to assess the effect of sediment derived from anthropogenic sources on beneficial use support. Water quality targets and supplemental indicators for sediment impairments include measures of the width/depth ratio, entrenchment ratio, percent of fine sediment on the stream bed and in pool tail-outs, risk and percentage of eroding banks, and macroinvertebrate metrics. The proposed water quality targets and supplemental indicators to help define sediment impairments are summarized in **Table 5-2** and are described in the sections which follow. No fine sediment targets (i.e. percent surface fines in riffles and pools) will be applied to the low gradient E streams in the Shields River TPA because these stream types naturally have high amounts of fine sediment, regional reference sediment values vary greatly, and there is insufficient internal reference data. Future surveys should document stable (if meeting criterion) or improving trends. Additional details regarding reference conditions and target development are contained in

Appendix C. The target values will be compared to measured values for each sediment impaired stream segment. If the results are consistent with the existing impairment determination, a TMDL will be provided. Site-specific conditions such as recent wildfires, natural conditions, and flow alterations within a watershed may warrant the selection of unique indicator values that differ slightly from those presented below, or special interpretation of the data relative to the proposed sediment indicator values.

Table 5-2. Targets for Sediment in the Shields River TPA

Water Quality Targets	**Proposed Criterion**
Percentage of fine surface sediment <6mm based on riffle pebble counts.	Comparable with reference values based on Rosgen Stream type. [a]
Percentage of fine surface sediment <2mm based on riffle pebble counts.	The value must not exceed **10-15%**.
Percentage of fine surface sediment <6mm based on a reach **average** from 49-point grid toss in pool tails.[b]	The value must not exceed **20%**.
Width/depth ratio, expressed as a reach **median** from channel cross-section measurements.[c]	Comparable with reference values based on Rosgen Stream type. [a]
Macroinvertebrates.	Mountain MMI $\geq$ 63 Low Valley MMI $\geq$ 48 Plains MMI $\geq$ 37 RIVPACS $\geq$ 0.80
Supplemental Indicators	**Proposed Criterion**
Entrenchment ratio, expressed as a reach **median** from channel cross-section measurements.[c]	Comparable with reference values. [a] This target only applies to B, C, and E stream types.
BEHI hazard rating, expressed as a reach **average**.[b]	Comparable with reference values based on Rosgen Stream type. [a]
Percentage of eroding banks, based on the sum of both left and right bank lengths per reach.	Eroding banks for less than **15%** of reach for B, C, and E type streams.
Anthropogenic sediment sources.	No significant sources identified based on field and aerial surveys.

[a] Based on the USFS channel morphology dataset and contained in **Appendix C**.
[b] The total number of measurements per reach was dependent on the number of features (i.e. pools and eroding banks).
[c] There were 5 cross section measurements per reach.

In addition to the sediment criteria listed above, Rosgen channel type departure was determined for all assessed reaches. Departure from natural stream type is used as an additional indicator of impairment, taking into account the variables driving the departure. Departure is determined based on morphological variables, such as entrenchment, width/depth ratio, sinuosity, or high enough percent fines to change the stream type.

Several of the water quality targets for sediment in the Shields TPA are based on regional reference data. It should be noted that the Montana DEQ defines “reference” as the condition of a water body capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a water body’s greatest potential for water quality given historic and current land use activities. Water bodies used to determine reference conditions are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. In

addition, this reference condition approach also does not reflect an effort to "turn back the clock" to conditions that may have existed before human settlement, but is intended to accommodate natural variations due to climate, bedrock, soils, hydrology, and other natural physiochemical differences when establishing threshold values for sediment indicators. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity.

5.4.1.1 Water Quality Targets

Percent Surface Fine Sediment in Riffles
The percent of surface fines less than 6 mm and 2 mm is a measurement of the fine sediment on the surface of a stream bed and is directly linked to the support of the cold water fishery and aquatic life beneficial uses. Increasing concentrations of surficial fine sediment can negatively affect salmonid growth and survival (Magee et al. 1996; Suttle et al. 2004) and macroinvertebrate abundance and taxa richness (Relyea et al. 2000; Mebane 2001; Zweig et al. 2001). The water quality target for the percent of fine sediment <6 mm and <2 mm on the streambed is based on feasibility, literature values for fish and other aquatic life, and departure beyond the regional reference. The target for sediment <6 mm varies from 12-29% depending on the Rosgen stream type (see **Appendix C, Table C-1**), and the target for sediment <2 mm is less than 10-15% for B and C stream types.

Percent Surface Fines in Pool Tail-Out Gravels
A particle size of 6 mm is commonly used to define fine sediment because of its potential to clog spawning redds and smother fish eggs by limiting oxygen availability (Irving and Bjornn 1984; Shepard et al. 1984). As an area where fish commonly spawn and excess sediment may accumulate if there are excess sediment loads and/or inadequate stream transport capacity, the percentage of surface fines in pool tails can indicate sediment supply/transport problems and support of coldwater fishery and aquatic life beneficial uses. Based on conditions within the Shields River TPA and available reference data, the water quality target for percent surface fine sediment <6 mm in pool tails is a reach average less than 20% for B and C stream types.

Width/Depth Ratio
The width/depth ratio is a fundamental aspects of channel morphology and provides a measure of channel stability, as well as an indication of the ability of a stream to transport and naturally sort sediment into a heterogeneous composition of fish habitat features (i.e. riffles, pools, and near bank zones). The reference values range from 7 to 31 depending on the Rosgen stream type (**Appendix C, Table C-1**), and a departure of the reach median width/depth ratio beyond the appropriate reference range will be used as a water quality target for sediment impairments.

Macroinvertebrates
Macroinvertebrate assemblages respond predictably to siltation with a shift in natural or expected taxa to a prevalence of sediment tolerant taxa over those that require clean gravel substrates. Macroinvertebrate bioassessments scores are an assessment of the macroinvertebrate assemblage at a site and are used by the Montana DEQ to evaluate impairment condition and the ability of a water body to support the aquatic life beneficial use. In 2006, Montana DEQ adopted impairment thresholds for bioassessment scores based on two separate methodologies: the Multi-Metric Index (MMI) method and the River Invertebrate Prediction and Classification System (RIVPACS) method. The macroinvertebrate target is to be equal to or greater than the applicable thresholds provided in **Table 5-2**.

5.4.1.2 Supplemental Indicators

Entrenchment Ratio
The entrenchment ratio describes the vertical containment of a stream, or how easily it can access its floodplain. Entrenchment is not as responsive to land-use changes within the watershed as the width/depth ratio, but a negative shift in entrenchment (toward a more entrenched state) is an indicator of channel instability. A departure of the reach median entrenchment ratio beyond the reference range for the appropriate stream type (**Appendix C, Table C-1**) will be used as a supplemental indicator for sediment impairments. The entrenchment ratios range from 1.8 to 5.1 and values greater than the reference range indicate the channel is not entrenched.

Bank Erosion Hazard Index (BEHI)
Stream flows, sediment loads, riparian vegetation, and streambank material all influence bank stability, which, in turn, influences sediment contribution to the stream. A bank erosion hazard index (BEHI) value beyond the reference range for the appropriate stream type (**Appendix C, Table C-1**) will be used as a supplemental indicator for sediment impairments. The reference BEHI values range from 23.6 to 31.7. Values less than the reference range indicate a low potential for bank erosion.

Percentage of Eroding Banks
The percent of eroding streambanks within a survey reach will be applied as a supplemental indicator for sediment impairments. Since streambank erosion is a natural process, this indicator will be used with caution. For example, just because eroding banks are present does not necessarily mean the erosion is human-induced or that there is an in-stream sediment problem. Additional information, such as observed bank trampling, removal of stabilizing vegetation, or increased water yield from timber harvest, will be considered. Departure from reference condition will apply when the percent of eroding banks within a survey reach exceeds 15% for B, C, and E type streams.

Significant Human Caused Sediment Sources
When there are no significant identified anthropogenic sources of sediment within the watershed of a 303(d) listed steam, no TMDL will be prepared since Montana's narrative criteria for sediment cannot be exceeded in the absence of human causes. Human induced and natural sediment sources will be evaluated using recently collected data in comparison with the reference dataset, along with field observations and watershed scale source assessment information obtained using aerial imagery and GIS data layers. Source assessment analysis will be provided by 303(d) listed water body in the Pollutant Sources and Loads Section (**Section 6.0**), with additional information in **Appendices E, F, and G**.

5.5 Summary of Existing Data

This section provides brief summaries of all available relevant sediment and habitat related water quality data for water bodies in the Shields River TPA appearing on the Montana 1996 and 2006 303(d) Lists.

5.5.1 Shields River

5.5.1.1 Aerial Surveys, Riparian Condition, and Stream Morphology

Most of the existing data for the Shields River is for the upper segment (MT43A001_012), upstream of Cottonwood Creek and the town on Clyde Park. In 1999, Montana Fish, Wildlife, and Parks documented conditions in the Shields River Watershed upstream of Clyde Park based on an aerial survey performed using a NRCS Rapid Aerial Assessment protocol (Tohtz 1999a). The survey noted extensive historical logging and removal of LWD near the headwaters, especially in the tributaries. The vegetation removal and an associated increase in runoff within the upper watershed were attributed to channel braiding and numerous depositional features. Downstream of the historically logged areas, agricultural land use (e.g. grazing, hay, and crop production) along the riparian corridor was cited as the primary cause of stream degradation. There was a clear distinction between sinuosity, frequency of pools and riffles, and the number of actively eroding banks in stretches with a healthy riparian zone versus those with degraded riparian vegetation. The conditions observed along the Shields River during the aerial assessment were very similar to those seen along most tributaries and are described in detail within the report.

In 2001, an aerial survey was conducted over the 41 river miles from Clyde Park to the boundary of the GNF (Inter-Fluve 2001). The survey divided the river into 12 sub-reaches based on geomorphic and hydrologic changes and was followed up by ground-truthing of riparian vegetation, identification of eroding banks, and collection of geomorphological characteristics at a minimally impacted section within each sub-reach. The study concluded that most of the upper segment of the Shields River is sediment transport limited as a result of irrigation practices and long-term drought. In addition to the effects of dewatering on fisheries habitat and the vigor of the riparian vegetation, historical clearing of native woody vegetation and continued encroachment by agriculture are also major factors in bank instability. The study also cited the role of episodic flooding in channel avulsion and downcutting within the highly erodible alluvial outwash that forms much of the river corridor in the upper segment.

In 2004, Confluence Consulting used USGS Digital Orthophoto Quarter Quad (DOQQ) aerial photos and GIS tools to assess sediment sources and stratify both 303(d) Listed segments of the Shields River based on existing versus potential Rosgen channel type, existing versus potential near bank vegetation type and density, and adjacent land use. After stratification, water quality monitoring and assessment tasks were conducted within ten representative reaches (**Map A-14**) with the intent of characterizing instream sediment conditions and bank erosion (Confluence 2004). The upper three reaches are on USFS land within the GNF and the remaining seven reaches are surrounded by private land. Data collected during this effort are presented and compared to sediment targets in **Section 5.6.1**.

5.5.1.2 Biological Data

Twelve macroinvertebrate samples have been collected at 5 sites between 1992 and 2005. Four of the sites are in the upper segment (above Cottonwood Creek) and one is in the lower segment by the mouth of the Shields River (**Map A-15**). All but one sample was collected by DEQ personnel according to the DEQ Standard Operating Procedures for Aquatic Macroinvertebrate Sampling (Bukantis 1998). The non-DEQ sample was collected at a Montana State University (MSU) site following USFS protocols (Heitke et al. 2006). Assessment reports from samples collected in 2000, 2001, and 2003 generally concluded that the composition of macroinvertebrate assemblages reflected a mixture of reach-scale habitat disturbance and minor effects from sedimentation (Bollman 2001; Bollman 2002a; Bollman 2004b). Habitat assessments were conducted during sampling and noted substrate embeddedness, fine sediment in pools, and a layer of fine sediment on the substrate. The bioassessment scores (MMI and RIVPACS) are presented in **Section 5.6.1**.

Algal samples were collected by DEQ personnel at two sites in 2000 and again in 2003 following DEQ. Conclusions drawn in the summary reports (Bahls 2001a; Bahls 2004), however will not be used as part of this document because the index used to assess algal impairment from sediment is currently being modified by DEQ.

Fish surveys conducted throughout the Shields River Watershed from 1999 to 2003 found that YCT are distributed throughout the watershed and are abundant in many tributaries (Tohtz 1999b; Shepard 2004). In general, YCT are most abundant in the tributaries in the eastern part of the watershed. In 1999 (Tohtz 1999b), population estimates in four eastern tributaries ranged from 280 to 958 YCT per mile, and Tohtz concluded the populations were well established, self-sustaining residents. Within the main stem Shields River, YCT abundance is low and mountain whitefish, brown trout, and brook trout are the dominant species. The YCT population within the watershed has had no to little introgression with rainbow trout (Shepard 2004; May et al. 2007). The Chadborne irrigation diversion on the main stem in the lower part of the watershed serves as a fish barrier that has limited upstream migration of rainbow trout and other species. During the fish surveys (Shepard 2004), habitat was noted to be generally good in most tributaries but low flows were seen in the lower portions of many tributaries and attributed to a combination of irrigation withdrawals and drought. Impacts from livestock grazing were widespread but areas of recovery were noted and likely a result of land use management changes and restoration projects including those listed in **Section 2.0**. Other prominent observed impacts to fish habitat included

roads, and timber harvest. Additionally, high levels of fine sediments were identified in several streams, but sources were unknown.

5.5.2 Antelope and Potter Creeks

5.5.2.1 Aerial Surveys, Riparian Condition, and Stream Morphology

In 2004, Antelope and Potter Creeks were evaluated and stratified in the same method as the Shields River. From this process, two representative reaches were selected for Antelope Creek and four were selected for Potter Creek (**Map A-14**). Riparian vegetation for both streams is typical of prairie streams, containing mostly grasses and upland shrubs; a comparison of photos from 1954 to 1998 indicated a minimal reduction in riparian woody vegetation along both streams. The aerial assessment of Antelope Creek noted that the channel has a very limited riparian buffer surrounded by irrigated hayfields. Minor evidence of grazing was seen during field reconnaissance in 2004, but streambanks were predominantly vegetated with little erosion. Aerial photo review and field visits in 2000 and 2004 confirmed that much of Antelope Creek is ephemeral, and the upper third of Potter Creek is ephemeral and well vegetated. During field visits, there were few signs of grazing in some areas, but extensive hoof shear and localized channel widening in others. In general, however, human-caused bank erosion is minimal and sources are limited to road sediment and grazing upstream of Cottonwood Reservoir, while hydromodification has resulted in actively eroding banks and channel widening downstream of the reservoir.

5.5.2.2 Biological Data

Both Antelope and Potter Creeks had one macroinvertebrate sample collected in August 2000 (**Map A-15**). Samples were collected by DEQ personnel according to the DEQ Standard Operating Procedures. The Antelope Creek macroinvertebrate sample showed some evidence of sediment deposition, but predominantly suggested nutrient enrichment and/or elevated water temperatures (Bollman 2002b). The Potter Creek macroinvertebrate sample included several taxa very tolerant of sediment and also suggested large-scale habitat disturbance and dewatering (Bollman 2002c). Habitat assessments performed during sampling noted moderate fine sediment deposition in Antelope and Potter Creeks. The bioassessment scores (MMI and RIVPACS) are presented in **Section 5.6.1**. One algal sample was also collected on both creeks in 2000 (Bahls 2001b), but, as with the Shields River, sediment-related conclusions drawn from the algal samples will not be used as part of this document because the index used to assess algal impairment from sediment is currently being modified by DEQ.

A fisheries survey of Antelope Creek in 2002 concluded flows in the lower portion of the stream are likely too low to support fish (Shepard 2004). Within the lower 7 miles of Potter Creek, white suckers, longnose sucker, longnose dace, and sculpins were found. Habitat observations during the fish survey included little to no riparian shade, a streambed mostly covered in silt, and impacts from Cottonwood Reservoir flows and livestock.

5.5.3 Other Data Sources

Other pertinent data and sources not listed above include that information found in Montana DEQ's Sufficient and Creditable Data (SCD) files. These files represent an aggregation of data utilized during the 303(d) assessment process. Where appropriate, these files will be referenced within this document.

5.6 Sediment Impairments Summary

This section presents summaries and evaluations of all available sediment related water quality data for the Shields River TPA appearing on the Montana 2006 and 1996 303(d) lists. A suite of water quality targets and supplemental indicators have been applied to either support the need for developing TMDLs or to suggest that more information is needed prior to TMDL development.

5.6.1 Water Body Comparisons to Targets

As described in **Section 5.4.1** and **Appendix C**, water quality targets were developed to assess sediment conditions in the Shields River TPA and to help measure the success of ongoing and future efforts to implement the TMDLs. The existing data in comparison to the targets and supplemental indicators are summarized in **Tables 5-3 and 5-4**. Analysis, discussion, and TMDL development determinations follow for each 303(d) Listed water body.

Table 5-3. Summary of Sediment Targets and Supplemental Indicators for all 303(d) Listed Water Bodies

Reach IDs are listed in an upstream to downstream direction. Shaded cells fail to meet their respective targets based on Rosgen Level II potential.

Water Body	Reach ID	Targets					Supplemental Indicators				
		Pebble Count		Grid Toss	Cross Section		Rosgen Level II		BEHI		
		Riffle % <6mm	Riffle % <2mm	Pool Tail % <6mm (mean)	W/D Ratio (median)	Entrenchment Ratio (median)	Existing	Potential	Score (mean)	Adjective Rating	% Eroding Bank
Shields	SR02	ND	ND	***87***	***19.2***	2.4	B3	B3	10.5	Low	4.4
Shields	SR02R	***32***	***27***	***92***	13.8	2.6	B3	B3	***36.0***	***High***	***19.4***
Shields	SR04	14	10	***30***	***33.3***	***3.3***	***D4/B4***	C4	0.0	Low	0.0
Shields	SR07	10	7	***37***	***34.4***	***2.6***	C4	C4	***40.2***	***High***	***17.0***
Shields	SR10	4	3	***56***	***39.2***	***3.2***	C4	C4	***35.7***	***High***	5.0
Shields	SR11	1	1	***85***	***31.3***	***1.5***	C4	C4	26.2	Mod	2.5
Shields	SR14	0	0	***75***	***46.5***	***2.0***	C4	C4	***35.5***	***High***	7.4
Shields	SR17	13	5	***77***	***55.3***	***1.5***	C4	C4	***31.1***	***High***	***16.5***
Shields	SR20	2	2	***32***	***43.1***	***1.1***	***F4***	C4	***34.6***	***High***	***17.9***
Shields	SR22	3	0	12	***40.2***	***2.4***	C4	C4	28.1	Mod	***17.8***
Antelope	AC04	ND	ND	ND	6.6	10.6	E	E	0.0	Low	0.0
Antelope	AC07	56	22	100	5.6	9.3	E4/6	E4/6	***37.0***	***High***	1.0
Potter	PT05	ND	ND	ND	5.6	10.9	E	E	0.0	Low	0.0
Potter	PT07	32	27	100	6.4	18.2	E4/5	E4	0.0	Low	0.0
Potter	PT08	30	29	99	***10.7***	***1.9***	***F4***	E4	***38.6***	***High***	9.3
Potter	PT08R	87	79	100	***11.1***	***1.4***	***F5***	E4	***39.1***	***High***	11.3

ND = no data collected

See **Appendices F and I** for raw data.

Table 5-4. Summary of Macroinvertebrate Indices for all 303(d) Listed Water Bodies
Shaded cells fail to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, Plains MMI ≥ 37, RIVPAC ≥ 0.80). Sites are listed in an upstream to downstream direction.

Biological Target					
Site ID	**Location Description**	**SiteClass**	**MMI**	**RIVPAC**	**Collected**
BKK128	Shields River near South Fork	Mountains	77.9	***0.46***	10/7/1992
MTST-006	Shields River near NFS land (MSU site)	Mountains	74.1	1.14	Unknown
Y02SHLDR01	Shields River below Hill Rd bridge	Low Valley	61.9	0.92	9/19/2000
Y02SHLR02	Shields River below Indian Creek Rd bridge	Low Valley	***25.7***	0.88	9/19/2000
Y02SHLR02		Low Valley	55.9	1.13	7/10/2003
BKK127	Shields River near mouth and Livingston	Low Valley	50.3	0.88	10/7/1992
Y03SHIER01		Low Valley	***45.4***	1.26*	7/23/2001
Y03SHIER01		Low Valley	***46.0***	1.13	8/28/2002
Y02SHLDR50		Low Valley	60.7	1.26*	7/10/2003
Y03SHIER01		Low Valley	***43.8***	1.01	7/18/2003
Y03SHIER01		Low Valley	62.7	1.38*	6/24/2004
Y03SHIER01		Low Valley	54.4	1.26*	7/16/2005
Y02ANTPC01	Antelope Creek near Clyde Park	Plains	38.8	1.01	8/11/2000
Y02POTRC01	Potter Creek above Cottonwood Reservoir	Plains	38.0	1.26	8/10/2000

*Meets the sediment target but suggests possible nutrient enrichment

5.6.1.1 Shields River

The Shields River originates at Fawn Creek in the GNF and flows in a southerly direction for approximately 62 river miles to the confluence with the Yellowstone River near Livingston, Montana. Approximately the first 7 miles flows through the Middle Rockies ecoregion, and the remainder of the river flows through the Northwestern Great Plains ecoregion. Aquatic life, coldwater fishery, and primary contact recreation beneficial uses in the Shields River (segments MT43A001_011 and MT43A001_012) were listed as impaired on the 1996 and 2006 Montana 303(d) lists because of alterations in stream-side or littoral vegetative covers, low flow alterations, physical substrate habitat alterations, and sedimentation/siltation.

Results and Discussion
Nine out of the 10 sites met the percent fines target for less than 6 mm and less than 2 mm in riffles. However, 9 of the 10 sites exceeded the percent fines target for pools by an average of 217%. Width to depth (W/D) ratios generally increase downstream, and all but one site exceeded the target. All eight sites with a potential Rosgen channel type of C4 failed to meet the entrenchment target and were on average 57% lower than the target of 5.1. For supplemental indicators, six of the assessment reaches exceeded the BEHI target with a high risk of erosion and five of the reaches exceeded the 15% target for eroding banks. Sites SR04 and SR20 had shifted from their potential Rosgen channel types.

The field data support the conclusions from the aerial surveys and field reconnaissance. Degradation of the riparian habitat has decreased bank stability, accelerated bank erosion, and resulted in channel widening and a decrease in entrenchment ratios throughout the river. This widening and reduction in access to the floodplain has concentrated flows within the channel, which can accelerate scouring during storm events. These factors coupled with drought and irrigation withdrawals make it difficult for the stream to effectively transport and deposit

sediment from instream and upland sources. The channel in reach SR04 and other parts of the upper watershed have become braided; this was seen during 2004 sampling, but was also noted during the 1999 aerial assessment (Tohtz 1999a) and attributed to excess sediment from historical logging practices. Riparian degradation near SR20 led to high erosion rates and channel widening, and it caused the reach to become entrenched and shift from a C channel to an F channel. The high percentage of fine sediment in pool tails is an additional indicator that the Shields River is sediment transport limited. All of the above factors are consistent with the existing impairment determination for coldwater fisheries uses due to excess fines in potential spawning areas and the loss of desirable habitat typically linked to high W/D ratios and decreased entrenchment ratio.

Out of 12 macroinvertebrate samples, one sample from a "Mountain" site failed to meet the RIVPAC threshold (0.8) and four samples from "Low Valley" sites failed to meet the MMI threshold (48). However, aquatic life at the Low Valley sites is not necessarily impaired because the RIVPAC score should be given more weight in the Low Valley if the two indices disagree (Feldman 2006) and the corresponding RIVPAC scores are all above the threshold. Although the Mountain sample (site BKK128) has a very low RIVPAC score, the MMI and RIVPAC scores for the other Mountain sample and the rest of the Low Valley samples are above the targets; the low RIVPAC score could be a result of localized impairment or sample error. Despite degraded habitat and the composition of several macroinvertebrate samples indicating a community shift because of sediment, it does not appear that excess sediment is impairing the macroinvertebrates within the Shields River.

Four of the Low Valley samples have a RIVPAC score greater than 1.2 and suggest there may be excess nutrients within the watershed. Although nutrients will not be addressed within this document, nutrients are often bound to sediment and may be indirectly influenced by a decrease in sediment inputs to the river.

TMDL Development Determination
Although excess sediment does not appear to be impairing macroinvertebrates, the high percentage of fines in the pools and impacted channel morphology results suggest that there is a reduction in the quality of and quantity of fish rearing and spawning habitat. Additionally, anthropogenic sources have increased sediment loading to the Shields River and diminished its ability to transport sediment, leading to additional loss in fish habitat as well as potential loss to other aquatic life habitat. These findings support the 303(d) Listing for sediment impairment, and a TMDL will be developed for sediment in the Shields River.

5.6.1.2 Antelope Creek

Antelope Creek (MT43A002_020) originates east of the Bridger Mountains and flows 10 miles before its confluence with the Shields River between Wilsall and Clyde Park. The upper 2 miles flows through the Middle Rockies ecoregion, and the remainder of the stream flows through the Northwestern Great Plains ecoregion. Field reconnaissance concluded that almost three-fourths of the stream is ephemeral. Aquatic life and coldwater fishery beneficial uses were listed on the 1996 and 2006 303(d) Lists as impaired because of solids (suspended/bedload) and alterations in stream-side or littoral vegetative covers.

The upper site on Antelope Creek (AC04) is approximately 7 miles from the headwater. The site is ephemeral and has sage brush growing in the channel; morphological data such as entrenchment ratio and W/D ratio were collected but no measurements of in-stream sediment were obtained.

Results and Discussion

Both sites on Antelope Creek were meeting their Rosgen channel type potential and were within the expected range for W/D ratio and entrenchment. The lower site had eroding banks with a high potential for erosion, but it only accounted for 1% of all the banks within the assessment reach. The percentage of fines in the riffles and pools was high, but is expected in an E4/E6 channel. There is only one macroinvertebrate sample from Antelope Creek, but both the MMI and the RIVPAC scores were above the impairment threshold, indicating no impairment to the macroinvertebrates. Although hay production and grazing are the primary land use along Antelope Creek and some riparian degradation has occurred, no significant anthropogenic sediment sources were identified.

Large floating algal mats were observed within Antelope Creek during field visits in 2000 and 2004 (**Figure 5-1**). Also, field reconnaissance and landowner contact during sampling in 2004 indicated that water within lower Antelope Creek is most likely irrigation return flow.

TMDL Development Determination

Field data and observations indicate that the suspended solids within Antelope Creek are actually suspended organic matter from an irrigation return and not excess anthropogenic sediment from the Antelope Creek watershed. As a result of this, a TMDL will not be developed for sediment in Antelope Creek. However, because this type of channel is extremely sensitive to riparian degradation, riparian best management practices identified in **Section 8.0** should be implemented to improve the riparian habitat and prevent further degradation. Additional monitoring is recommended to confirm that water quality issues within the lower part of Antelope Creek are associated with the irrigation return and determine the associated pollutants that may be impairing beneficial uses. Future development of a nutrient TMDL for Antelope Creek may be necessary.


Figure 5-1. Algal Growth in Antelope Creek during 2004 Assessment Work

5.6.1.3 Potter Creek

Potter Creek flows for 25 river miles from the headwaters to its mouth near Wilsall and is entirely contained within the Northwestern Great Plains ecoregion. Aquatic life and coldwater fishery beneficial uses in Potter Creek (segment MT43A002_010) were listed as impaired on the 1996 and 2006 Montana 303(d) lists because of low flow alterations, sedimentation/siltation, and solids (suspended/bedload).

Results and Discussion
The field data show significant changes between channel geomorphology and bank erosion upstream and downstream of Cottonwood Reservoir. Both reaches above the reservoir (PT05 and PT07) are achieving their potential Rosgen channel type, while those downstream of the reservoir (PT08 and PT08R) have both shifted from E channels to F channels. This shift is also illustrated in the difference between W/D ratios and entrenchment. The mean reach W/D ratios were 5.6 and 6.4 upstream of the reservoir, but 10.7 and 11.1 downstream of the reservoir. Upstream of the reservoir, the stream can easily access its floodplain, but downstream of the reservoir, the channel is entrenched. Although the percentage of eroding banks meets the target for all reaches, no actively eroding banks were seen upstream of Cottonwood Reservoir, but those found at the downstream reaches had a high erosion potential. Also, although there is no target for fine sediment in E channels, and Potter Creek is expected to have naturally high levels of fine sediment, the large difference among values suggest excess sedimentation. Reaches PT07 (upstream of Cottonwood Reservoir) and PT08 (downstream of Cottonwood Reservoir) had very similar percentages of riffle fines while site PT08R (downstream of the reservoir) had 87 % fines <6 mm and 79% fines <2 mm (compared to 32% and 27% at PT07 and PT08, respectively). These results suggest that flow releases from Cottonwood Reservoir have contributed to increased vertical and lateral erosion downstream of the reservoir.

Macroinvertebrates were collected above Cottonwood Reservoir, and both the MMI and RIVPAC scores are above the impairment threshold. Although macroinvertebrates downstream of Cottonwood Reservoir are likely under more stress than those at the sample site, the available sample indicates that the macroinvertebrate in Potter Creek are not impaired.

TMDL Development Determination
Sediment and habitat data support the 303(d) listing for sediment impairment on Potter Creek. Excess levels of fine sediment could definitely be impairing the aquatic life and coldwater fishery beneficial uses by reducing the quality of and decreasing the quantity of fish rearing and spawning habitat. Data suggest minor impacts upstream of Cottonwood Reservoir from grazing practices and roads and moderate impacts downstream of the reservoir caused primarily by flow modification. As a result, a sediment TMDL will be prepared for Potter Creek. Sediment targets will likely be modified in the future as additional data are collected.

5.6.2 TMDL Development Determination Summary

A summary of the 1996 and 2006 303(d) Listing status, TMDL development determination for each water body segment is shown below in **Table 5-5**. All sediment-related listing causes discussed in **Section 1.0** (**Table 1-1**) are listed as sediment in the table below.

Table 5-5. Summary of TMDL Development Determinations

Stream Assessment Unit	Probable Cause	2006 303d	1996 303d	Pursue TMDL Development	Additional Monitoring and/or Further Impairment Review Recommended
Shields River (headwaters to Cottonwood Cr) MT43A001_012	**Sediment**	X	X	Yes	No
Shields River (Cottonwood Cr to mouth) MT43A001_011	**Sediment**	X	X	Yes	No
Antelope Creek MT43A002_020	**Sediment**	X	X	No	Yes
Potter Creek T43A002_10	**Sediment**	X	X	Yes	No

5.7 Data Gaps, Uncertainty, and Adaptive Management

5.7.1 Data Gaps

Within this section, the current condition of target and supplemental indicator variables was compared to reference conditions for each 303(d) Listed water body. The data collection effort for this TMDL collected as much pertinent data as possible given time and resource constraints. In some cases, there were low sample numbers or the distribution of sample sites was not ideal. Overall, the largest data gap is local reference data. Internal reference sites were sought along 303(d) Listed streams during project planning, but because sediment impairment can result from reach scale and watershed scale activities and large scale disturbances occurred throughout the watershed historically, no appropriate internal reference reaches were found. Data gaps are summarized within **Section 8.0**, and filling in the data gaps is part of the monitoring suggestions within that section.

5.7.2 Uncertainty and Adaptive Management

A degree of uncertainty is inherent in any study of watershed processes related to sediment. The assessment methods and targets used in this study to characterize impairment and measure future restoration are each associated with a degree of uncertainty. Field measurements were conducted by a team, so there is some inherent bias in the assessment methods because of having multiple observers. This bias is minimized, however, by all field personnel adhering to standard sampling procedures. Some parameters may over or under estimate the fraction of fine sediment, but a suite of targets and supplemental indicators is used to reduce bias by any single parameter, and parameters with a higher level of uncertainty are considered with less weight and used as supplemental indicators. While uncertainties are an undeniable fact of TMDL development, this document will include a monitoring and adaptive management plan to mitigate and reduce uncertainties in the field methods, targets, and supplemental indicators.

For the purpose of this document, adaptive management relies on continued monitoring of water quality and stream habitat conditions, continued assessment of impacts that human activities and natural conditions have on water quality and stream habitat conditions, and continued assessment of how aquatic life and cold-water fish, particularly cutthroat trout, respond to changes in water quality and stream habitat conditions. Adaptive management addresses important considerations, such as feasibility and uncertainty in establishment of targets. For example, despite implementation of all restoration activities (**Section 8.0**), the attainment of targets may not be feasible due to natural disturbance such as forest fires, flood events, or landslides. The targets established in the document are meant to apply under median conditions of natural background and natural disturbance. The goal is to ensure that management activities are undertaken to achieve loading approximate to the TMDLs within a reasonable time frame and to prevent significant excess loading during recovery from significant natural events. Additionally, it is possible that the natural potential of some streams will preclude achievement of some targets. For instance, natural geologic and other conditions may contribute sediment at levels that cause a deviation from numeric targets associated with sediment. Conversely, some targets may be underestimates of the potential of a given stream and it may be appropriate to apply more protective targets upon further evaluations. Supplemental indicators are used to help with these determinations. In light of all this, it is important to recognize that the adaptive management approach provides the flexibility to refine targets as necessary to ensure protection of the resource or to adapt to new information concerning target achievability.

As part of this adaptive management approach, increased land use activities should be tracked along with increased monitoring of target parameters before and after land use activities should always be considered. For example, coal bed methane development (CBM) is a concern for some stakeholders within the Shields River TPA, and there may be a future need for additional monitoring sites and targets to track CBM-associated changes to water quality. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP compliance inspections to a complete measure of target parameters below the project area before the project and after completion of the project. Cumulative impacts from multiple projects must also be a consideration. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed. Under these

circumstances, additional targets and other types of water quality goals may need to be developed to address new stressors to the system, depending on the nature of the activity.

SECTION 6.0
POLLUTANT SOURCES AND LOAD ESTIMATES

This section presents a review of sediment source assessments conducted to facilitate the development of this TMDL. Significant sediment sources identified within the Shields watershed that were assessed for the purposes of TMDL development include:
- Unpaved roads
- Upland erosion
- Streambank erosion

For each impaired water body segment, sediment loads from each source category were estimated based on field surveys, watershed modeling, and load extrapolation techniques. Source assessment methods and results are given below.

6.1 Source Assessment Methods

6.1.1 Unpaved Roads

Improperly designed roads can directly affect aquatic ecosystems. Roads fundamentally disrupt natural drainage patterns by diverting water and preventing water infiltration into soil. Roads can affect both the volume of water available as surface runoff and the efficiency with which water flows through a watershed. Roads can also contribute sediment to waterways from direct erosion on cut-and-fill slopes. In addition, improperly designed roads can increase the magnitude and frequency of mass failures and landslides.

Sediment loading from unpaved roads was assessed in the Shields River TPA. This assessment employed GIS, field data collection and sediment modeling to estimate sediment inputs from the unpaved road network to the stream network. The GIS exercise identified 2,448 contributing road segments within a 200 foot buffer of streams. Of the contributing road segments, 59% were from stream crossings and 41% were from parallel road segments. Of the roads, 19% were on USFS land and the remaining roads were on private or State property.

Sediment delivery to streams from the identified roadways was estimated using the Washington Road Surface Erosion Model (WARSEM). WARSEM is an empirical model, and estimates sediment production and delivery based on road surfacing, road use, underlying geology, precipitation, road age, road gradient, road prism geometry, cut slope factors, and other factors. Most of the parameters must be field verified, and data were collected from 32 stream crossings throughout the Shields River Watershed. Data independent of site conditions were modified to reflect conditions within Montana. Results were extrapolated based on the road type (e.g. 4WD, local, ranch, and highway) and whether the road was parallel to the stream or crossed it. To address sediment from unpaved roads in the TMDLs and allocations that follow in **Section 7.0**, the WARSEM analysis was also run using several BMP scenarios. Sample locations and a more detailed description of this assessment can be found in *Sediment Contribution from Roads*, which is included as **Appendix D.**

While the TMDL was being prepared, the GNF completed several road decommissioning and road improvement projects in the TPA, particularly in the Bangtail, Willow, and Smith Creek watersheds (USFS 2004; USFS 2006a; USFS 2007). The analysis presented does not include these recent improvements.

6.1.2 Hillslope Erosion

Hillslope erosion occurs throughout the Shields River Watershed in areas ranging from steep, forested headwaters to relatively flat agricultural valley bottoms. Natural hillslope erosion rates can be accelerated as a result of human disturbances such as silviculture, urban development, and agricultural practices.

Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE) model and sediment delivery to the stream was predicted using a sediment delivery ratio. The USLE results are useful for source assessment as well as determining allocations for human-caused upland erosion. This model provided an estimate of existing sediment loading from upland sources and an estimate of potential sediment loading reductions through the application of best management practices (BMPs). Because the plant canopy and type of tillage practices can influence erosion, potential load reductions are calculated by adjusting factors within the model that are associated with land management and cropping practices (C-factors). Additional information on the upland erosion modeling can be found in *Sediment Contribution from Hillslope Erosion*, which is included as **Appendix E**.

6.1.3 Bank Erosion

Streambank erosion is an inherent part of channel evolution and contributes sediment to stream systems in response to a combination of climatic and physiographic factors. However, anthropogenic impacts, including poor land management, road systems, riparian vegetation removal, and/or channel alterations can result in elevated rates of streambank erosion and subsequent impacts to beneficial uses.

Sediment loading from streambank erosion was assessed in the Shields River TPA in 2004 by performing BEHI measurements and evaluating the Near Bank Stress (NBS) (Rosgen and Silvey 1996; Rosgen 2001). Measurements were made at 16 reaches along Potter Creek and the Shields River (discussed in **Section 5.0**) and at 13 additional tributary reaches within the TPA (**Map A-16**). BEHI scores were determined at each eroding streambank based on the following parameters: bank height, bankfull height, root depth, root density, bank angle, and surface protection. In addition to BEHI data collection, surrounding land use practices and adjacent streamside vegetation condition were recorded.

Assessment reaches were previously stratified using aerial photos and GIS tools as described in **Section 5.5.1** and **Appendix F**. Because riparian vegetation is crucial for bank stabilization, the existing and potential vegetation type and density were determined for all reaches. Average erosion rates associated with each reach type (based on land use and vegetation) were used to extrapolate bank erosion to each subwatershed within the TPA. To estimate the sediment reductions that could be achieved by the application of BMPs, the loading rate was calculated for

the potential vegetation type and density of each reach type. A more detailed description of this assessment can be found in *Sediment Contribution from Stream Bank Erosion*, which is included as **Appendix F**.

6.2 Source Assessment Results

This section summarizes the current sediment load estimates from three broad source categories of road erosion, streambank erosion, and hillslope erosion. EPA sediment TMDL development guidance for source assessment states that the basic source assessment procedure includes compiling an inventory of all sources of sediment to the waterbody and using one or more methods to determine the relative magnitude of source loading, focusing on the primary and controllable sources of loading (EPA 1999). Additionally, regulations allow that loadings "...may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading," (Water quality planning and management, 40 CFR § 130.2(I)). The source assessment conducted for this TMDL evaluated loading from the primary sediment sources using standard DEQ methods, but the sediment loads presented herein represent relative loading estimates within each source category and, as no calibration has been conducted, should not be considered as actual loading values. Rather, relative estimates provide the basis for percent reductions in loads for each source category. Until better information is available and the linkage between loading and in-stream conditions becomes clearer, the loading estimates presented here should be considered as an evaluation of the relative contribution from sources and source areas that will be further refined in the future through adaptive management.

6.2.1 Roads

Based on the WARSEM analysis, roads contribute 280 tons of sediment per year to streams in the Shields River Watershed. Of the total load from roads within the Shields River TPA, roads within the Potter Creek Watershed contribute 11 tons of sediment annually. In general, private/State roads are contributing most of the sediment from unpaved roads (**Table 6-1**), and unpaved road segments that are parallel to water bodies contribute a very small amount of sediment compared to unpaved road crossings (**Table 6-2**). Within the Shields River TPA, parallel road segments contribute less than 2% of the total sediment from roads. Sediment delivery from roads is highest in the lower Shields River with the Chicken Creek and Upper Brackett Creek subwatersheds contributing the most sediment (24 and 23 tons/year, respectively; **Figure 6-1**). However, if road-associated sediment from each subwatershed is normalized by the miles of contributing road, the Elk Creek and Rock Creek subwatersheds contribute the greatest annual load (1.6 and 1.4 tons/mile/year, respectively; **Appendix D, Table D-2**). **Appendix D** contains sediment loads for the Shields River TPA and by 6th code HUC (**Map A-17**), and it also includes the contribution within each 6th code HUC by road ownership and road type.

Table 6-1. Sediment Loads from Unpaved Roads in the Shields River and Potter Creek Watersheds by Road Ownership

Watershed	Road Ownership	Miles of Road Segments within 200 feet of a stream	Total existing sediment load (tons/year)
Shields River	Private/State	233	255
	USFS	34	25
Potter Creek	Private/State	12	11

Table 6-2. Sediment Loads from Unpaved Roads in the Shields River and Potter Creek Watersheds by Road Orientation

Watershed	Road Orientation	Miles of Road Segments within 200 feet of a stream	Total existing sediment load (tons/year)
Shields River	Parallel	109	4
	Crossing	158	276
Potter Creek	Parallel	4	< 1
	Crossing	8	11

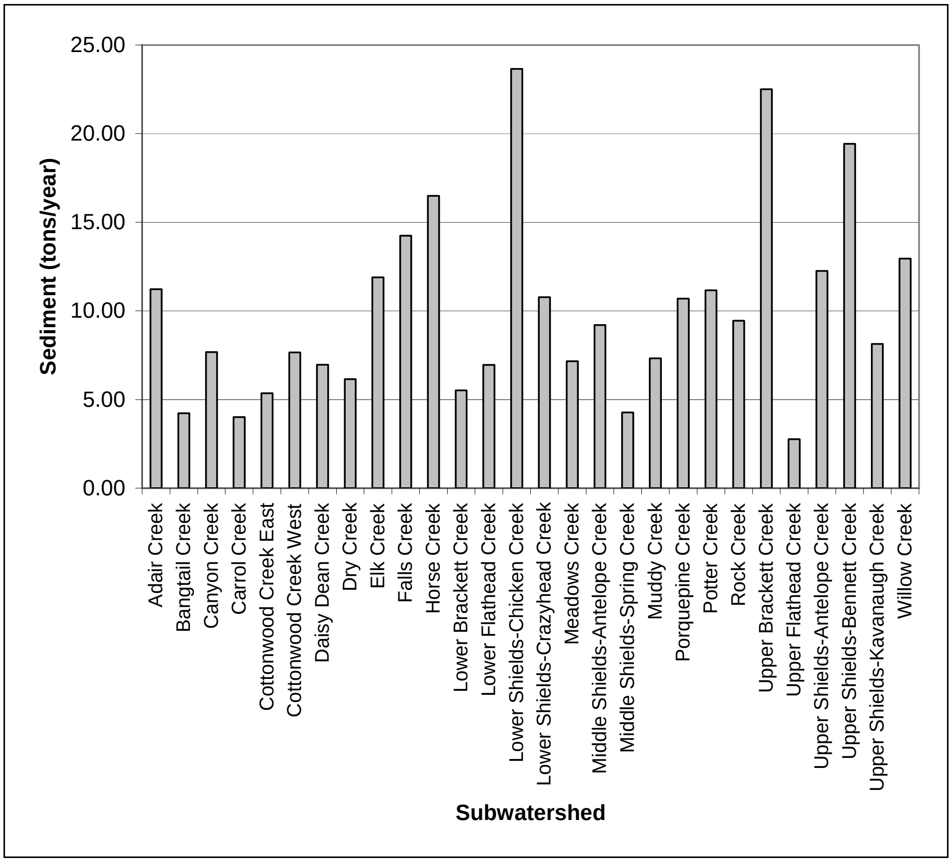

Figure 6-1. Existing Annual Sediment Load (ton/year) from Unpaved Roads in Subwatersheds within the Shields River TPA

6.2.2 Upland Erosion

Based on the USLE analysis, hillslope erosion contributes approximately 157,000 tons of sediment per year to streams in the Shields River Watershed, with 43% being attributable to anthropogenic sources that can be reduced through the application of BMPs. Within the Potter Creek Watershed, hillslope erosion contributes approximately 5,700 tons of sediment per year. Roughly 34% of that load is from controllable anthropogenic sources. Similar to the land cover breakdown, agriculture is the predominant source within the Potter Creek Watershed and the Shields River Watershed. **Table 6-3** shows the hillslope erosion by land cover type for both watersheds. By unit area, the loads from subwatersheds range from 0.11 to 0.65 tons/acre/year, with the greatest loads coming from the Bangtail Creek and Upper Brackett Creek watersheds in the southwestern part of the Shields River TPA (**Appendix E, Table E-5**). Total sediment loading from hillslope erosion was highest in the Upper Brackett Creek and Rock Creek watersheds (**Figure 6-2**), which are in the lower part of the Shields River Watershed, just south of Clyde Park. Total and normalized loads are presented for each 6th digit HUC (**Map A-17**), by land cover, and by owner in **Appendix E.**

Table 6-3. Sediment Loads from Hillslope Erosion by Land Cover Type for Watersheds of 303(d) Listed Water Bodies

Land Cover Type	Sediment Load (tons/yr)	
	Shields River	Potter Creek
Natural Sources	9,400	17
Grazing	110,000	4,200
Cropland	35,000	1,500
Silviculture	1,700	0
Total Load	157,000	5,700

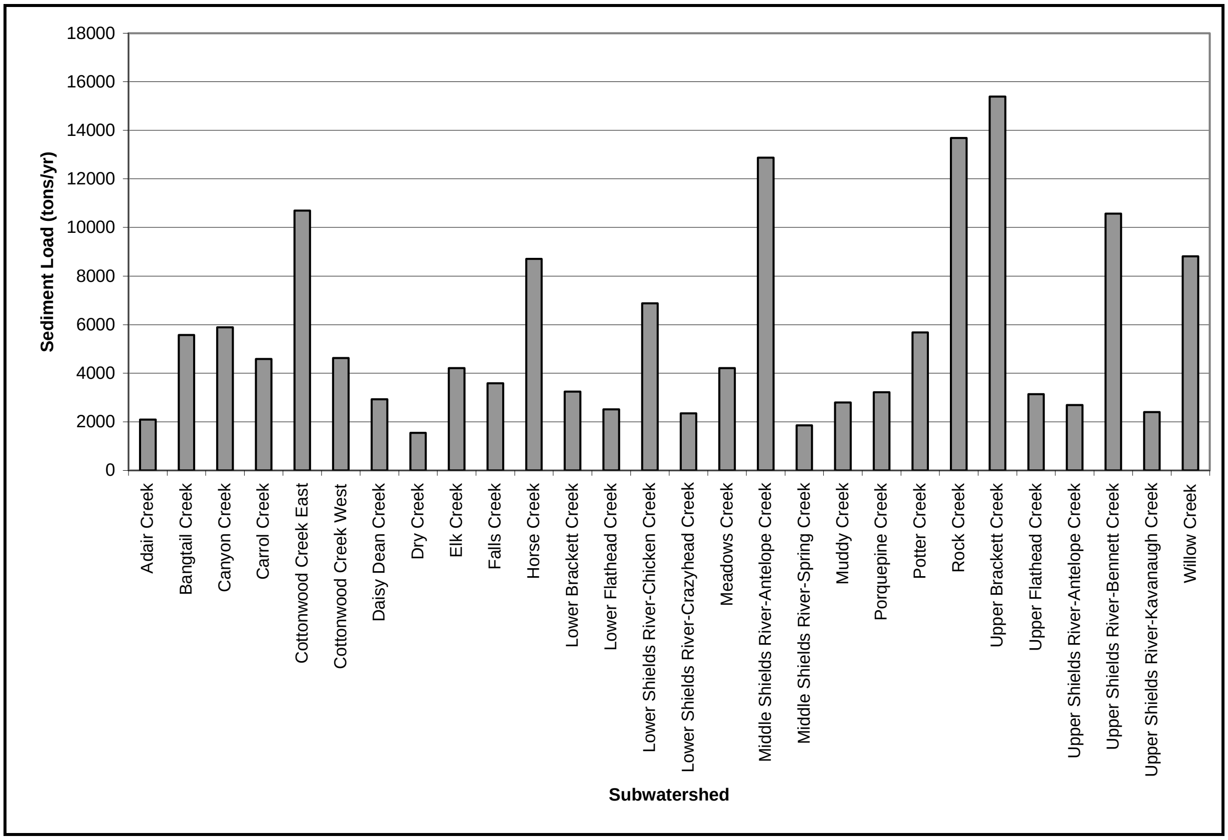

Figure 6-2. Existing Annual Sediment Load (tons/year) from Upland Erosion by Subwatersheds within the Shields River TPA

6.2.3 Bank Erosion

The assessment method excluded 100% naturally eroding banks from the extrapolation and potential loads are assumed to be a combination of natural loads and anthropogenic loads associated with the use of reasonable land, soil, and water conservation practices. Based on the BEHI analysis and extrapolation, bank erosion contributes 103,000 tons of sediment annually to water bodies within the Shields River TPA. As with unpaved roads and hillslope erosion, the Rock and Chicken Creek subwatersheds within the lower Shields Watershed are substantial sources, but the Potter Creek Watershed is also a large source of streambank erosion (**Figure 6-3**). When the miles of stream per subwatershed are taken into account, the Spring, Kavanaugh, and Chicken Creek subwatersheds contribute the most sediment from bank erosion (**Appendix F, Table F-4**). Approximately 8,100 tons of sediment is delivered to streams within the Potter Creek Watershed from eroding banks each year. Loads are presented for each 6th digit HUC (**Map A-17**) and by ownership in **Appendix F**.

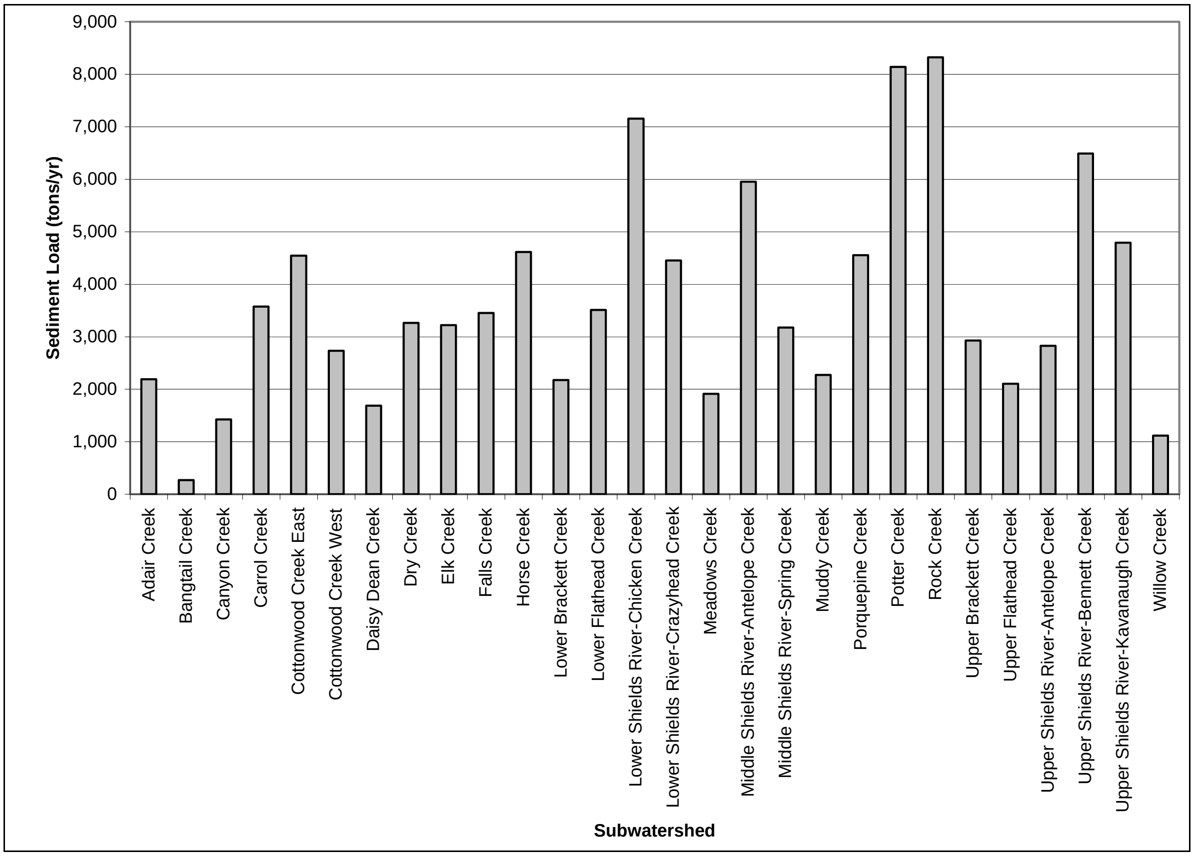

Figure 6-3. Existing Annual Sediment Load (tons/year) from Streambank Erosion by Subwatersheds within the Shields River TPA

6.3 Source Assessment Summary

From all assessed sources, the annual sediment load within the Shields River Watershed is 260,000 tons and within the Potter Creek Watershed is 14,000 tons (**Table 6-4**). Each source type has different seasonal loading rates and the relative percentage from each source category does not necessarily indicate its importance as a loading source. For instance, the roads and hillslope assessments focus on annual sediment loading whereas the bank erosion assessment is based on bank retreat rates associated with large flow events. Additionally, the different source assessment methodologies introduce differing levels of uncertainty, as discussed in the following section (**Section 6.4**). However, the modeling results for each source category, and the ability to proportionally reduce loading with the application of improved management practices (**Appendices D, E, and F**), provide an adequate tool to evaluate the relative importance of loading sources (i.e. subwatersheds and/or source types) and to focus water quality restoration activities for this TMDL analysis.

Table 6-4. Summary of Existing Sediment Loads (tons/year) from Unpaved Roads, Hillslope Erosion, and Bank Erosion

Source	Shields Watershed (tons/year)	Potter Creek Watershed (tons/year)
Unpaved Roads	280	11
Upland Erosion	157,000	5,700
Streambank Erosions	103,000	8,100
Total Load	**260,000**	**14,000**

6.4 Uncertainty

A degree of uncertainty is inherent in any study of watershed processes related to sediment. Limited field work was conducted for the modeling effort and best professional judgment was used in conjunction with regional data and literature values during model development. Incorporating local empirical data into future modeling efforts could help decrease uncertainty associated with source assessments. Sediment limitations in many streams in the Shields River TPA relate to a fine sediment fraction found on the stream bottom, while sediment modeling employed in the Shields River TPA examined all sediment sizes. In general, roads and uplands produce mostly fine sediment loads, while streambank erosion can produce all sizes of sediment. Additionally, the USLE hillslope assessment predicts total sediment loads that arrive at the subwatershed or watershed outlet, while the streambank erosion assessment estimates the sediment yield entering the stream along its continuum. Therefore, since sediment source modeling may under-estimate or over-estimate natural inputs due to selection of sediment monitoring sections and the extrapolation methods used, model results should not be taken as an absolutely accurate account of sediment production within each watershed. Instead, source assessment model results should be considered used as a tool to estimate sediment loads and make general comparisons of sediment loads from various sources.

Cumulatively, the source assessment methodologies address average sediment source conditions over long timeframes. Sediment production from both natural and human caused sources is driven by storm events. Pulses of sediment are produced periodically, not uniformly through time. Separately, each source assessments methodology introduces differing levels of uncertainty. For example, the road erosion method focuses on sediment production and sediment delivery locations from yearly precipitation events. The analysis did not include an evaluation of road culvert failures, which tend to add additional sediment loading during large flood events and would therefore increase the average yearly sediment loading if calculated over a longer time frame. Road loading also tends to focus in upper areas of watersheds where there is often limited hillslope or bank erosion loading. The bank erosion method focuses on both sediment production and sediment delivery and also incorporates large flow events via the method used to identify bank area and retreat rates. Therefore, a significant portion of the bank erosion load is based on large flow events versus typical yearly loading. The hillslope erosion model focuses primarily on sediment production across the landscape during typical rainfall years. Sediment delivery is partially incorporated based on distance to stream (**Appendix E**). The significant filtering role of near stream vegetated buffers (riparian areas) is not fully incorporated into the hillslope analysis, resulting in proportionally high modeled sediment loads from hillslope erosion relative to the amount of sediment actually delivered to streams.

Undersized culverts are also a potential sediment source, but were not assessed within the scope of this project. The risk of culvert failure is related to the frequency and size of storm events. Total failure can result in a large sediment pulse, but for undersized culverts, even smaller events can flush excess instream sediment downstream and cause culverts to become fish passage barriers. Due to the uncertainty associated with sediment source assessment modeling, **Section 8.0** includes a monitoring and adaptive management plan to account for uncertainties in the source assessment results.

SECTION 7.0
TMDLS, ALLOCATIONS, AND MARGIN OF SAFETY

7.1 TMDLs and Allocations

Based on the sediment source assessment, TMDLs and LAs will be developed for the Shields River and Potter Creek. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. More specifically, a TMDL is the sum of waste load allocations (WLAs) for point sources and LAs for nonpoint sources and natural background sources. In addition, the TMDL includes a MOS that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. The allowable pollutant load must ensure that the water body being addressed by the TMDL will be able to attain and maintain water quality standards regardless of seasonal variations in water quality conditions, streamflows, and pollutant loading. Because there are no point sources within the Shields River TPA, WLAs are excluded and TMDLs are expressed by the following equation:

$$TMDL = \Sigma LA + MOS$$

The sediment TMDL process presented in the main document for the Shields River TPA will adhere to this TMDL loading function, but use an average annual sediment yield source assessment, a percent reduction in loading allocated among sources, and an inherent MOS. A percent reduction approach is used because there is uncertainty associated with the loads derived from the source assessment, and using the estimated sediment loads creates a rigid perception that the loads are absolutely conclusive. A percent reduction allocation also considers the whole watershed as a source area and fits into a watershed wide water quality restoration planning approach. The TMDL for each 303(d) listed water body is expressed as an overall percent reduction in the sediment load and is derived from the sum of the percent reduction allocations to varying sources.

Because there are no point sources and sediment generally has a cumulative effect on beneficial uses, an annual expression of the TMDLs was determined as the most appropriate timescale to facilitate TMDL implementation. EPA encourages TMDLs to be expressed in the most applicable timescale, but also requires TMDLs to be presented as daily loads (Grumbles 2006); daily loads are provided in **Appendix G**.

7.1.1 Deriving Allocations

The percent reduction allocations are based on the modeled BMP scenarios for each major source type (i.e. unpaved roads, upland erosion, and streambank erosion) and reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments. Percent reductions are expected to be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. The allocation for roads was determined by assuming 40% of roads would be upgraded without paving and the contributing length would be reduced at 60% of roads – this combination of BMPs is not a

formal goal, but an example of how reductions can be achieved. Based on literature values of the effectiveness of upgrading roads and reducing contributing lengths, this combination would reduce the contribution from road sediment by 60%. The health of vegetation near the stream is a major factor in streambank stability and erosion rates, and was used to allocate to streambank erosion. Near bank vegetation condition and corresponding erosion rates at banks of varying stability were used to determine percent reductions that could be achieved by applying BMPs within the riparian zone. Allocations for agricultural upland sources were derived by modeling the reduction in sediment loads that will occur by increasing ground cover through the implementation of BMPs. Examples include providing off-site watering sources, limiting livestock access to streams, conservation tillage, precision farming, and establishing riparian buffers. The allocation to agricultural sources includes both present and past influences, and is not meant to represent only current management practices. Many of the restoration practices that address current land use will reduce pollutant loads that are influenced from historic land uses. Additional information regarding BMPs is contained in **Section 8.0** and **Appendices D, E, and F**.

7.2 Shields River

The Shields River was listed as impaired due to siltation on both the 2006 and 1996 303(d) Lists. The sediment contribution from unpaved roads, hillslope erosion, and eroding banks was assessed using methods summarized in **Section 6.0** and detailed in **Appendices D, E, and F**. Based on the results of the source assessment, the primary anthropogenic sources are bank erosion and upland sources associated with agriculture.

The current estimated sediment load is 260,000 tons per year. Through the application of BMPs, it is estimated that the sediment load could be reduced by 42% per year (**Table 7-1**). This reduction could be achieved by an allocation to roads for a 60% reduction and an allocation to eroding banks for 39% reduction. The allocation for upland sources includes a 36% reduction in grazing and 80% reduction in cropland. Logging is currently a very small source of sediment (<1% of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from logging activities, but logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). **Figure 7-1** contains the existing loads and percent reductions by subwatershed. The total maximum daily sediment load for the Shields River is expressed as a 42% reduction in total average annual sediment load.

Table 7-1. Sediment Allocations and TMDL for the Shields River

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment LAs
Roads		280	60% reduction
Eroding Banks		103,000	39% reduction
Upland Sediment Sources	**Silviculture**	1,700	0% reduction
	Grazing	110,000	36% reduction
	Cropland	35,000	80% reduction
	Natural Sources	9,400	0% reduction
Total Sediment Load/TMDL		260,000	42% reduction

* A significant portion of bank erosion loads after BMPs is a component of the "natural load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

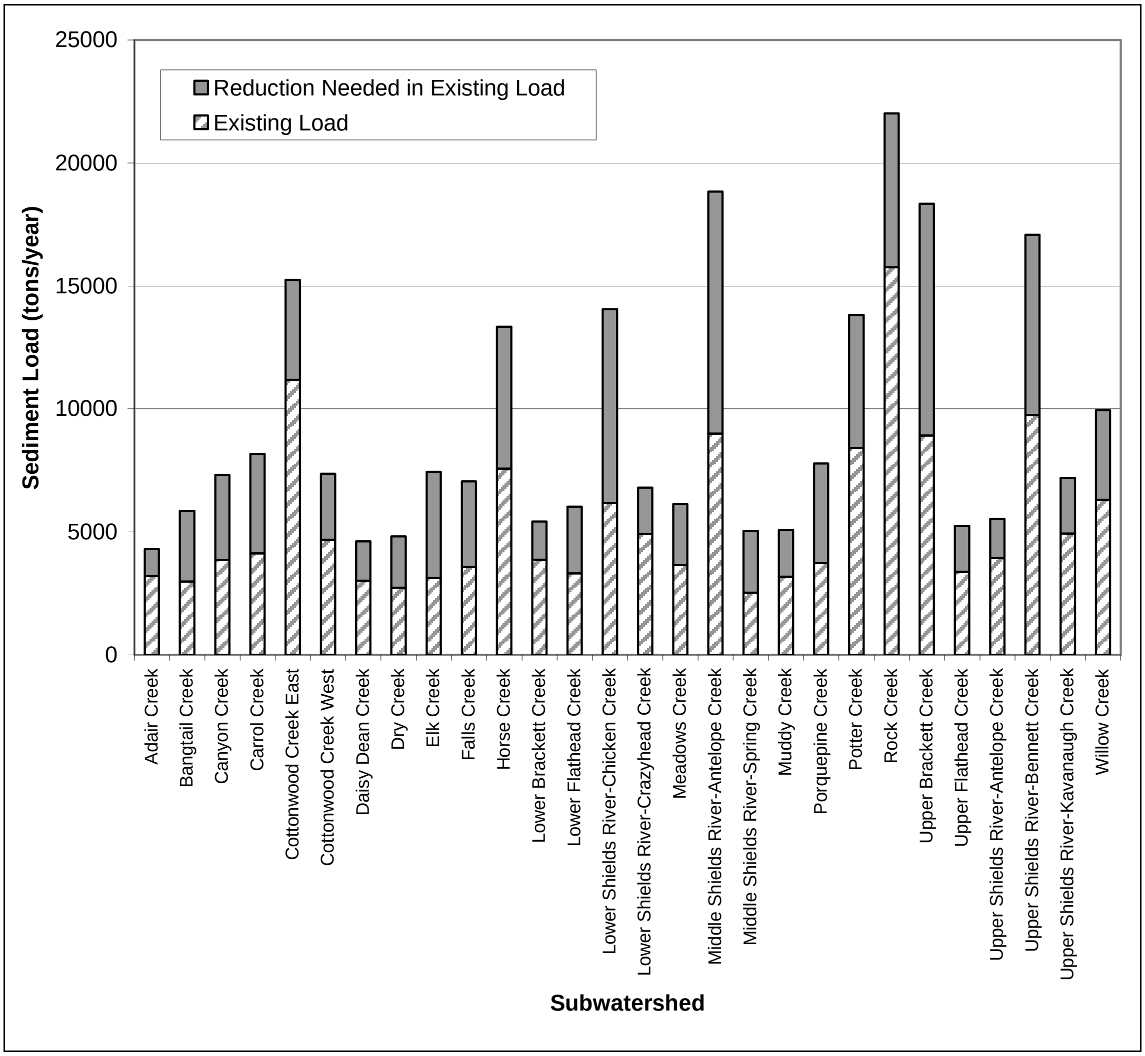

Figure 7-1. Existing Loads and Reductions Needed for Subwatersheds within the Shields River TPA

7.3 Potter Creek

Potter Creek was listed as impaired due to siltation on both the 2006 and 1996 303(d) Lists. The sediment contribution from unpaved roads, hillslope erosion, and eroding banks was assessed. Based on the results of the source assessment, the primary anthropogenic sources are bank erosion and upland sources associated with agriculture. The current estimated sediment load is 14,000 tons per year. Through the application of BMPs, it is estimated that the sediment load could be reduced by 39% per year (**Table 7-2**). This reduction could be achieved by an allocation to roads for a 60% reduction and an allocation to eroding banks for 43% reduction. The allocation for upland sources includes a 19% reduction in sediment from grazing practices and a 78% reduction in sediment derived from cropland. The total maximum daily sediment load for Potter Creek is expressed as a 39% reduction in total average annual sediment load.

Table 7-2. Sediment Allocations and TMDL for Potter Creek

Sediment Sources		Current Estimated Load (Tons/Year)	Potential Estimated Sediment Load with BMPs (Tons/Year)
Roads		11	60% reduction
Eroding Banks		8,100	43% reduction
Upland Sediment Sources	**Grazing**	4,200	19% reduction
	Cropland	1,500	77% reduction
	Natural Sources	17	0% reduction
Total Sediment Load/TMDL		14,000	39% reduction

* A significant portion of the remaining bank erosion loads after BMPs is also a component of the "natural load," though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

7.4 Future Growth and New Activities

There is potential for new sediment sources from future activities within the Shields River Watershed. Future developments within the Shields River Watershed may have a negative impact on beneficial use support of coldwater fisheries and aquatic life. Potential future development includes timber harvest, road construction and maintenance, subdivision development, and increased recreational pressure. Park, Meagher, and Gallatin Counties all have setback regulations in place for new subdivisions (DEQ, 2007) which should help limit encroachment onto streams and riparian areas. The GNF Travel Plan (USFS 2006a) discusses measures the USFS is taking to reduce existing and potential impacts to water quality from roads and recreational pressure within the GNF. Throughout the Shields River TPA, care should be taken to avoid include practices such as road encroachment onto water bodies, the addition of riprap along stream banks, placement of undersized culverts, and the removal of LWD and riparian vegetation in the stream corridors. Other negative impacts with the potential to increase sediment loads may arise on a site specific basis. Future actions in the watershed that could increase sediment loads or further disturb stream channel sediment transport capacity should support the implementation strategy (**Section 8.1**) within this document and implement all reasonable land, soil, and water conservation practices to mitigate effects to beneficial uses of water bodies within the Shields River TPA.

7.5 Margin of Safety

An implicit MOS is provided by conservative assumptions for sediment loading, including accounting for seasonality, which is designed to ensure restoration goals will be sufficient to protect beneficial uses. The MOS is to ensure that target reductions and allocations are sufficient to sustain conditions that will support of beneficial uses. An additional MOS is provided through the use of multiple targets and supplemental indicators and an adaptive management approach that includes provisions for modifying or altering targets and water quality goals based on monitoring outlined in the **Section 8.0**.

7.6 Uncertainty and Adaptive Management

The source assessments used as the basis for the percent reduction allocation assessed all sizeable sediment sources, but a few small sources may have been overlooked because of budgetary and temporal limitations of the TMDL project. EPA sediment TMDL development guidance for source assessment states that the basic source assessment procedure includes compiling an inventory of all sources of sediment to the waterbody and using one or more methods to determine the relative magnitude of source loading, focusing on the primary and controllable sources of loading (EPA 1999). Additionally, regulations allow that loadings "...may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading," (Water quality planning and management, 40 CFR § 130.2(I)). If the allocations are followed, sediment loads are expected to be reduced to a degree that the sediment targets are met and beneficial uses are no longer impaired.

Because of the uncertainty in the source assessment, the allocations are established as percent load reductions rather than absolute load reductions. Sediment source assessment results are useful for determining the largest sources within each watershed and are useful, along with consideration of restoration costs, to determine an allocation strategy based on economic costs and environmental benefits. Due to current BMP implementation, allocated percent reductions may not be feasible at all locations. Conversely, the source assessment did not account for riparian buffers and associated reductions in sediment loading from upland erosion; the existing load from upland erosion may be lower due to current riparian conditions, and additional reductions will be achievable in many areas with the improvement of riparian buffers. Although the bank erosion assessment estimated percent reductions via improved riparian habitat, some eroding banks may require bank stabilization as well. Uncertainty in loading estimates is addressed through an adaptive management approach where the TMDL and allocations from this document can be revised as additional information is collected. Adaptive management is part of the MOS and requires long-term monitoring to track BMPs and track stream condition to determine if targets have been achieved. This approach allows management recommendations and practices to be revised if targets have not been met. Monitoring recommendations are detailed in **Section 8.0**.

The loads and allocations established in the document are meant to apply under median conditions of natural background and natural disturbance. Under some natural conditions, such as large wildfires or extreme flow events, it may not be possible to satisfy all targets, loads, and allocations. The goal is to ensure that management activities are undertaken to achieve loading approximate to the TMDLs within a reasonable time frame and to prevent significant excess loading during recovery from significant natural events.

Noticeable improvement in habitat and reduction in sediment loading will not occur until most types of restoration mechanisms or management based activities have been in place for several years or more. Habitat improvements due to grazing BMPs should be observable within 3 to 5 years after project implementation. Water quality improvement may not be noticeable within the first several years, as it may take up to 10 years for sediment to flush through the system,

depending on flow management, climate, and the magnitude of excess deposition in different stream reaches. Therefore sediment reductions to meet the allocations will be a long-term goal.

SECTION 8.0
IMPLEMENTATION AND MONITORING STRATEGY

8.1 Introduction

This section includes the recommended restoration implementation and monitoring strategy for the Shields River TPA. Implementation of the restoration strategy and the continued and refined application of reasonable land, soil, and water conservation practices are expected to decrease pollutant loading to streams in the Shields River TPA. Implementation ensures that TMDL targets and Montana water quality standards are met over time, eventually resulting in full support of beneficial uses. The implementation strategy discusses BMPs by source type and implementation priorities. Although TMDLs specifically address pollutants and measures to reduce pollutant loading will often improve pollution issues, several BMPs within this section specifically address relevant sources of pollution, such as flow and habitat alterations. Recommendations are based on the source assessment completed for this document as well as existing literature and stakeholder feedback.

A key component in the success of the implementation strategy is adaptive management. Adaptive management is essentially a loop in which restoration activities (i.e. BMPs) are implemented, monitoring is conducted to evaluate the success of restoration in meeting targets and supporting beneficial uses, and based on an assessment of monitoring results and lessons learned during implementation, adjustments are then made, if necessary, to the next phase of restoration.

A time element for nonpoint source restoration activities is not explicit in the document because most restoration projects rely upon public funding programs, local and private funding match, local efforts to apply for funds, and landowner participation. A time frame for restoration projects on public land is also not specified because annual budget fluctuations for the agencies are unpredictable. An objective of the TMDL project is to provide a tool to public land management agencies and private landowners to acquire funds for future restoration projects identified in the document. A list of watershed priorities as identified by the SVWG is contained in **Appendix H**.

The following are the primary goals of this restoration implementation strategy:

- Ensure full recovery of aquatic life beneficial uses to all impaired and threatened streams identified by the State of Montana within the Shields River TPA
- Avoid conditions where additional water bodies within the Shields River TPA become impaired
- Work with landowners and other stakeholders in a cooperative manner to ensure implementation of water quality protection activities
- Continue to monitor conditions in the watershed to identify any additional impairment conditions, track progress toward protecting water bodies in the watershed, and provide early warning if water quality starts to deteriorate

8.2 Role of DEQ

The DEQ does not implement TMDL pollutant reduction projects for most activities, but can provide technical and financial assistance for stakeholders interested in improving their water quality. The DEQ will work with participants to use the TMDLs as a basis for developing locally driven Watershed Restoration plans (WRP), administer funding specifically to help fund water quality improvement and pollution prevention projects, and can help identify other sources of funding. An implementation plan is usually part of a locally lead watershed restoration effort. The local implementation strategy, if developed, should consider the findings of the Shields River Watershed Water Quality Planning Framework and Sediment TMDLs and incorporate restoration approaches if feasible within the locally lead framework.

8.3 Agency and Stakeholder Coordination

Because most NPS reductions rely on voluntary measures, it is important that local landowners, watershed organizations, and resource managers continue to work collaboratively with local and state agencies to achieve water quality restoration and meet water TMDL targets and load reductions. Specific stakeholders and agencies that have been and will likely continue to be vital to restoration efforts include the SVWG (previously the Upper Shields Watershed Association and the Southern Crazy Mountain Watershed Group), Park County CD, USFS, NRCS, DNRC, FWP, and DEQ. Other organizations and non-profits that may provide assistance through technical expertise, funding, educational outreach, or other means include Montana Water Trust, Northern Plains Resource Council, Montana Water Center, University of Montana Watershed Health Clinic, and MSU Extension Water Quality Program.

8.4 BMP Recommendations by Source

General management recommendations are outlined for major sources of pollutants in the Shields River Watershed. BMPs form the foundation of the management recommendations, but are only part of the restoration strategy. Recommendations may also address evaluating current use and management practices. In some cases, a larger effort than implementing new BMPs may be required to address sources of impairment. In these cases BMPs are usually identified as a first effort, and an adaptive management approach will be used to determine if further restoration approaches are necessary to achieve all beneficial uses.

8.4.1 Agriculture

Agricultural BMPs include a wide range of management options for grazing and crop land that have broad application throughout the watershed. In general, these are sustainable agricultural practices that promote attainment of conservation objectives while meeting agricultural production goals. The BMPs aim to prevent availability, transport, and delivery of sediment by a combination of minimizing sediment delivery, reducing the rate of runoff, and intercepting sediment transport. The appropriate BMPs will differ by landowner and are recommended to be part of a comprehensive farm/ranch plan.

8.4.1.1 Grazing

The key strategy of the recommended grazing BMPs is to develop and maintain healthy riparian vegetation and minimize disturbance of the stream bank and channel. The primary recommended BMPs for the Shields River Watershed are providing off-site watering sources, limiting livestock access to streams and hardening the stream at access points, planting woody vegetation along stream banks, and establishing riparian buffers. Although bank revegetation is a preferred BMP, in some instances bank stabilization may be necessary prior to planting vegetation. Other general grazing management recommendations and BMPs to address grazing sources of pollutants and pollution are listed below (**Table 8-1**). Further information on grazing BMPs can be obtained from the sources listed in **Table 8-1** and in **Appendix A** of Montana's NPS Management Plan (DEQ, 2007).

Table 8-1. Example Grazing Best Management Practices.

BMP and Management Techniques	Sources
Design a grazing management plan and determine the intensity, frequency, duration, and season of grazing to promote desirable plant communities and productivity of key forage species.	MDNRC, 1999
Monitor livestock forage use and adjust grazing strategy accordingly.	MDNRC, 1999
Maintain adequate vegetative cover to prevent accelerated soil erosion, protect streambanks and filter sediments. Set target grazing use levels to maintain both herbaceous and woody plants. No grazing unit should be grazed for more than half the growing season of key species.	MDNRC, 1999 NRCS, 2002
Ensure adequate residual vegetative cover and regrowth and rest periods. Periodically rest or defer riparian pastures during the critical growth period of plant species.	MDNRC, 1999 Mosley et al., 1997
Distribute livestock to promote dispersion and decomposition of manure and to prevent the delivery of manure to water sources.	MDNRC, 1999
Alternate season of use from year to year in a given allotment or pasture.	MDNRC, 1999 NRCS, 2002
Time grazing to reduce impacts based on limiting factors for system recovery. For example, early spring use can cause trampling and compaction damage when soils and streambanks are wet. Fall and early winter grazing can encourage excessive browse on willows.	MDNRC, 1999 NRCS, 2002
Place salt and minerals in uplands, away from water sources (ideally ¼ mile from water to encourage upland grazing). Periodically rotate feed and mineral sites. Keep salt in troughs and locate salt and minerals in areas where soils are less susceptible to wind or water erosion.	MDNRC, 1999 Mosley et al., 1997
Create riparian buffer exclosures through fencing or develop riparian pastures to be managed as a separate unit through fencing. Fencing should be incorporated only where necessary. Water gaps can be included in riparian fencing.	MDNRC, 1999

8.4.1.2 Cropland

The primary strategy of the recommended cropland BMPs is to minimize the amount of erodible soil, reduce the rate of runoff, and intercept eroding soil before it enters water bodies. The main BMP recommendations for the Shields River Watershed are vegetated filter strips (VFS) and riparian buffers. Both of these methods reduce the rate of runoff, promote infiltration of the soil (instead of delivering runoff directly to the stream), and intercept sediment. Effectiveness is typically about 70% for filter strips and 50% for buffers (DEQ 2007). Filter strips and buffers are most effective when used in conjunction with agricultural BMPs that reduce the availability of erodible soil such as conservation tillage, crop rotation, stripcropping, and precision farming. Additional BMPs and details on the suggested BMPs can be obtained from NRCS and in **Appendix A** of Montana's NPS Management Plan (DEQ 2007).

8.4.2 Roads

Through the application of BMPs, it is estimated that the sediment load could be reduced by 57%. This road sediment reduction represents the estimated sediment load that would remain if 40% of the roads were upgraded by one level without paving (e.g. upgrading a native dirt road to a pitrun road) and all contributing road treads, cut slopes, and fill slopes were reduced on 60% of roads. This method of achieving a reduction in sediment load was selected as an example to illustrate the potential for sediment reduction through BMP application and is not a formal goal. Achieving this reduction in sediment loading from roads may occur through a variety of methods at the discretion of local land managers and restoration specialists. Road BMPs can be found on the Montana DEQ or DNRC websites and within Montana's NPS Management Plan (DEQ, 2007). Examples include:

- Providing adequate ditch relief up-grade of stream crossings.
- Constructing waterbars, where appropriate, up-grade of stream crossings.
- Instead of cross pipes, using rolling dips on downhill grades with an embankment on one side to direct flow to the ditch. When installing rolling dips, ensure proper fillslope stability and sediment filtration between the road and nearby streams.
- Insloping roads along steep banks with the use of cross slopes and cross culverts.
- Outsloping low traffic roads on gently sloping terrain with the use of a cross slope.
- Using ditch turnouts and vegetative filter strips to decrease water velocity and sediment carrying capacity in ditches.
- For maintenance, grading materials to the center of the road and avoiding removing the toe of the cutslope.
- Preventing disturbance to vulnerable slopes.
- Using topography to filter sediments; flat, vegetated areas are more effective sediment filters.
- Where possible, limit road access during wet periods when drainage features could be damaged.

8.4.2.1 Road Crossings

Although culverts were not part of the source assessment, they can be large sources of sediment, and should be included in the restoration strategy. A field survey should be conducted and combined with local knowledge to prioritize culverts for restoration. As culverts fail, they should be replaced by culverts that pass a 100 year flood on fish bearing streams and at least 25 year events on non fish bearing streams. Culverts should be at grade with the streambed, and inlets and outlets should be vegetated and armored. Some road crossings may not pose a feasible situation for upgrades to these sizes because of road bed configuration; in those circumstances, the largest size culvert feasible should be used.

Another consideration for culvert upgrades will be providing fish passage. Montana FWP is currently investigating ways to make the Chadborne irrigation diversion a complete barrier to rainbow trout while allowing genetically pure YCT to migrate upstream and throughout the Shields watershed. During the assessment and prioritization of culverts, additional crossings

should be assessed for streams where fish passage is a concern. Because of the threat to Yellowstone cutthroat trout from non-native fish, each fish barrier should be assessed individually to determine if it functions as an invasive species and/or native species barrier. These two functions should be weighed against each other to determine if each culvert acting as a fish passage barrier should be mitigated. Montana FWP can aid in determining if a fish passage barrier should be mitigated, and, if so, it should be involved in culvert design. If funding is available, culverts should be prioritized and replaced prior to failure.

8.4.3 Irrigation and Flow Management

Irrigation and flow management is one of the biggest issues affecting water quality in the Shields River TPA. Three water bodies are on the 2006 and 1996 303(d) Lists for flow alterations (**Table 1-1**), Shields River, Rock Creek, and Cottonwood Creek, and low flow regularly affects fisheries habitat in several other tributaries (Inter-Fluve 2001; Shepard 2004; FWP 2005). Increasing instream flows will not only improve fish and other aquatic life habitat, but will also increase the capacity of the Shields River and its tributaries to transport sediment. Local coordination and planning are especially important for flow management because State law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana's water quality law (MCA 75-5-705).

Irrigation practices and water use efficiency have been studied within the Shields Watershed (Compston 2002; Dolan 2005). Some general recommendations from the studies include lining ditches with high seepage losses, installing measuring devices in ditches to better match need to usage, converting suitable areas to sprinkler irrigation, and changing points of diversion. Besides improving use efficiency and conveyance, water leasing can be used to promote water conservation and improve streamflow. Instream water leasing allows for the transfer of water rights from a consumptive use to instream flows to protect the fishery resource. Additionally, money earned from water leasing may help fund improvements to the irrigation network (Dolan 2007). An appropriator may make a temporary change by simply changing the purpose and place of use, or by leasing the water right to another party. Entities that have programs for leasing water for instream flows include Montana FWP, Trout Unlimited, and the Montana Water Trust. Although Montana does not currently have the legal framework to allow water banking, it could be an additional option if the laws are modified in the future. Water banking allows a water right holder to move his right temporarily to a new use, new user, or new place of use within the same drainage and automatically revert to its original operation at the end of the temporary use. This practice transfers water, not water rights, and could be particularly useful during critical periods, such as drought or late-season. As with other BMPs, water conservation measures should be implemented on a case by case basis. In some instances, improving irrigation efficiency can reduce the amount of water returning to a stream and increase late-season demand (Dolan 2005); it is recommended that DNRC be consulted regarding projects to improve irrigation efficiency.

As a largely agricultural watershed containing unhybridized Yellowstone cutthroat trout, it is important to maximize water usage for both agricultural and aquatic life uses. This need is recognized by the SVWG and is included as a goal in its 2008 Work Plan (**Appendix H**). Because of the complexity of water usage and water rights, collaboration by stakeholders is very important. As recommended in the study by Dolan (2005), irrigators should develop a

management plan for larger ditches within the Shields watershed (e.g. the Big Ditch) and also a drought plan. This level of organization will help irrigators to better manage water usage, track increased efficiency, identify areas that need improvement, and to ensure that efforts to save water for instream flow end up in the stream.

8.4.4 Other Issues

This section includes a discussion of issues that are not currently primary limiting factors to water quality, but are a consideration for long-term watershed management and restoration. All of the previous and following management issues are interrelated; therefore, a long-term holistic approach to watershed management will provide the most effective results.

8.4.4.1 Bank hardening/riprap/revetment/floodplain development

Bank hardening has historically occurred in several places throughout the watershed. Although it is necessary in some instances, it generally redirects channel energy and exacerbates erosion in other places. Bank armoring should be limited to areas with a demonstrated infrastructure threat. Where deemed necessary, apply bioengineered bank treatments to induce vegetative reinforcement of upper bank, reduce stream scouring energy, and provide shading and cover habitat. Limit infrastructure threats by reducing floodplain development through land use planning initiatives (e.g. the Park County Subdivision Regulations).

8.4.4.2 Logging

Currently, timber harvest is not significantly affecting sediment production in the Shields River TPA, but harvesting will likely continue in the future within the GNF and on private land. Future harvest activities should be conducted by all landowners according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana SMZ Law (77-5-301 through 307 MCA). The Montana Forestry BMPs cover timber harvesting and site preparation, harvest design, other harvesting activities, slash treatment and site preparation, winter logging, and hazardous substances. While the SMZ Law is intended to guide commercial timber harvesting activities in streamside areas (i.e. within 50 feet of a water body), the riparian protection principles behind the law can be applied to numerous land management activities (i.e. timber harvest for personal use, agriculture, development). Prior to harvesting on private land, landowners or operators are required to notify the Montana DNRC. DNRC is responsible for assisting landowners with BMPs and monitoring their effectiveness. The Montana Logging Association and DNRC offer regular Forestry BMP training sessions for private landowners.

8.4.4.3 Noxious Weeds

Invasive weeds are a growing concern in the Shields River TPA and most areas of Montana. The Park County Extension Office and Park County Weed Board have been active in public education for noxious weeds and have sprayers available for free for public use (Park County Extension 2007). The Park County Weed Board has a weed plan that is updated annually, requires new subdivisions to develop a weed management plan, and encourages landowners to use biocontrol or large animal grazing. Also, the SVWG developed a noxious weed map in 2001

that it is in the process of updating (SVWG 2008). The widespread effort to manage and combat noxious weeds across land ownership boundaries throughout the watershed should continue. NRCS and County Weed Management Specialists can provide information about weed management BMPs.

8.5 Restoration Priorities

It is important to note that while certain land uses and human activities are identified as sources and causes of water quality impairment, the management of these activities is of more concern than the activities themselves. This plan does not advocate for the removal of land uses or human activities to achieve water quality restoration objectives. It does however advocate for improving water quality and preventing degradation of water quality as a result of current or future land use management practices and human activities. As listed in **Tables 2-1** and **2-2**, management improvements have already been implemented by private landowners, USFS, and FWP in recent years in many parts of the watershed.

This document contains general restoration priorities; site-specific priorities will be determined by local landowners and stakeholders. A list of restoration priorities as identified by the SVWG is contained in **Appendix H** and will be used in conjunction with this document to guide restoration efforts by private landowners. As specific restoration sites are assessed, it is important to determine the underlying causes of problem areas and to address those during restoration implementation as well. Otherwise, time and resources may be spent to restore sediment source areas that will continue to be problem areas.

As discussed in **Section 5.3**, the effect of different sources can change seasonally and be dependent on the magnitude of storm/high flow events. Therefore, restoration activities within the Shields River Watershed should focus on all major sources – upland erosion, streambank erosion, and unpaved roads. For each major source, BMPs will be most effective as part of a management strategy that focuses on critical areas within the watershed, which are those areas contributing the largest pollutant loads or are especially susceptible to disturbance.

Although it is important to apply BMPs to all land management activities, the most critical area for hillslope erosion is within 350 feet of a water body (**Appendix E**). Therefore, activities that increase the health of riparian areas and reduce bank erosion, such as grazing BMPs and maintenance of riparian buffers or vegetative filter strips, can also substantially decrease sediment loading from hillslope erosion. This makes riparian and bank erosion protection BMPs the most effective method of reducing sediment loading throughout the majority of the Shields watershed.

For roads, the results of the source assessment (**Appendix D**) are a good starting point for locating the greatest sources of road erosion, but because of the amount of extrapolation in the model, a survey should be conducted to prioritize which roads (and culverts) should be improved. The field work conducted for the road assessment revealed numerous roads with long segments contributing sediment to water bodies. The most effective way to reduce sediment erosion from roads will be to focus on the longest road segments and the biggest problem areas.

8.6 Adaptive Management Approach

An adaptive management approach is recommended to manage costs as well as achieve success in meeting the water quality standards and supporting all beneficial uses. This approach works in cooperation with the monitoring strategy and allows for adjustments to the restoration goals (**Section 8.1**) or pollutant targets, TMDLs, and/or LAs, as necessary. These adjustments would take into account new information as it arises.

The adaptive management approach is outlined below:

- TMDLs and Allocations: The analysis presented in this document assumes that the load reductions proposed for each of the listed streams will enable the streams to meet target conditions and further assumes that meeting target conditions will ensure full support of all beneficial uses. Much of the monitoring proposed in this section of the document is intended to validate this assumption. If it looks like greater reductions in loading or improved performance is necessary to meet targets, then updated TMDL and/or allocations will be developed based on achievable reductions via application of reasonable land, soil, and water conservations practices.
- Water Quality Status: As restoration activities are conducted in the Shields River TPA and target and supplemental indicator variables move towards reference conditions, the impairment status of the 303(d) Listed waterbodies is expected to change. An assessment of the impairment status will occur after significant restoration occurs in the watershed.

8.7 Monitoring Strategy

The monitoring plan discussed in this section and is an important component of watershed restoration, a requirement of TMDL development under Montana's TMDL law, and the foundation of the adaptive management approach. While targets and LAs are calculated using the best available data, the data are only an estimate of a complex ecological system. The MOS is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring plan in place allows for feedback on the effectiveness of restoration activities (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long term monitoring programs also provide technical justifications to modify restoration strategies, targets, or LA where appropriate. Some field procedures have been revised since data collection for TMDL development; all future monitoring should adhere to standard DEQ protocols.

The monitoring strategy presented in this section is meant to provide a starting point for the development of more detailed and specific planning efforts regarding monitoring needs; it does not assign monitoring responsibility. It is expected that monitoring recommendations provided will assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans to meet aforementioned goals.

8.7.1 Follow-up Monitoring

The primary focus of this section is to identify weak links in the existing source assessments. Since data collection for the source assessment, DEQ has modified several aspects of the procedure, including incorporating riparian buffer health into the hillslope model and better quantifying the contribution from bank erosion sources within the BEHI assessment. These modifications, as well as others identified by DEQ when follow-up monitoring commences, should be included if possible during follow-up monitoring. Strengthening source assessments should also include assessment of future sources as they arise. For example, CBM development is a concern for some stakeholders within the Shields River TPA, and there may be a future need for additional monitoring sites and targets to track CBM-associated changes to water quality. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP compliance inspections to establishing baseline conditions and measuring target parameters below the project area before the project and after completion of the project. Suggested monitoring parameters include sulfate, electrical conductivity, sodium adsorption ratio, and total dissolved solids. Cumulative impacts from multiple projects must also be considered. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed. Under these circumstances, additional targets and other types of water quality goals may need to be developed to address new stressors to the system, depending on the nature of the activity. If these new sources occur, new data should be used to update TMDL allocations.

Additional monitoring is recommended to gain a better understanding of natural sediment loading from mass wasting and streambank retreat rates. Particularly in the upper Shields Watershed, there are several very steep areas where mass wasting events have occurred. To better understand the link between sediment loading and in-stream conditions, it would be helpful to gain a better understanding of natural loading from mass wasting events. Streambank retreat rates are part of the equation for calculating sediment loading from near-stream sediment sources for sediment TMDLs and allocation. The current sediment TMDLs are calculated using literature values for streambank retreat rates. Measuring streambank retreat rates on water bodies within the Shields River TPA would be useful to verify or revise the current TMDLs and would also be useful for completing or revising sediment TMDLs in other watersheds throughout Montana in similar settings. Bank retreat rates can be determined by installing a series of bank pins at different positions on the streambank at several transects in sites placed in a range of landscape settings and stability ratings. Bank erosion is documented after high flows and throughout the year for several years to capture retreat rates under a range of flow conditions. Aerial photos may also be available to assist with tracking bank retreat rates (SVWG 2008).

The irrigation efficiency studies (Compston 2002; Dolan 2005) could be expanded upon to examine the effects of irrigation improvements, such as converting to sprinkler irrigation and installing ditch lining on surface and ground water. Additionally a feasibility study is needed to determine if the irrigation infrastructure can be modified to reduce irrigation returns and retain more instream flow. Because improving efficiency could diminish surface and groundwater return flows and possibly exacerbate dewatering issues in the watershed (Dolan 2005), caution should be used when implementing irrigation improvements. Therefore, once feasible irrigation improvements are identified and planned, additional monitoring should be conducted to quantify

irrigation effects to ground water conditions and ultimately surface water before project implementation. Monitoring should be conducted before, during, and after water use periods for several years. As irrigation efficiency projects are implemented, effectiveness monitoring should occur to see how much water is saved by each project. An economic analysis of each irrigation efficiency project should also occur to determine the cost of the saved water. This effort would need local initiation and funding would likely come from both local match and also Federal and State sources.

Flow monitoring is also recommended for water bodies with chronic flow problems to determine minimum flows needed to support fish and other aquatic life. At a minimum, this is recommended for the Shields River, Cottonwood Creek, and Rock Creek, but should also be extended to other water bodies with low flow problems. Montana FWP can provide guidance and technical assistance for developing minimum flow requirements. The establishment of minimum flow requirements does not obligate landowners or infringe on water rights, but can be used as a tool to guide water management decisions during implementation of irrigation and water conservation BMPs.

In addition to affecting sediment transport, low flows can contribute to elevated water temperatures, which can diminish the ability of a water body to support fish and other aquatic life. Montana FWP has several years of temperature data throughout the watershed (Endicott 2008); DEQ should coordinate with FWP to incorporate temperature data into future 303(d) water quality assessments within the Shields TPA.

A study is also recommended on Potter Creek to examine alternatives for reducing bank erosion from outflows from Cottonwood Reservoir. Most problems on Potter Creek are downstream of the reservoir and without modifications to the timing and magnitude of reservoir releases, bank stabilization and riparian BMPs downstream of the reservoir will have limited effectiveness.

8.7.2 Implementation and Restoration Effectiveness

As defined by Montana State Law (75-5-703(9)), DEQ is required to evaluate progress towards meeting TMDL goals and water quality standards after implementation of reasonable land, soil, and water conservation practices. If this evaluation demonstrates that water quality standards and beneficial use support have not been achieved within five years, DEQ is required to conduct a formal evaluation of progress in restoring water quality and the status of reasonable land, soil, and water conservations practice implementation to determine if:

- The implementation of a new or improved phase of voluntary reasonable land, soil, and water conservation practices is necessary.
- Water quality is improving, but more time is needed for compliance with water quality standards.
- Revisions to the TMDL are necessary to achieve applicable water quality standards and full support of beneficial uses.

Although DEQ is responsible for TMDL-related monitoring, it is envisioned that much of it could occur under coordination with land managers and local interests. Implementation and

restoration monitoring may include summaries of such items as the length of road upgraded to BMP standards, length of decommissioned roads, fish passage barriers corrected, or tracking riparian shade disturbances, as well as the estimated impact of these actions in terms of decreased pollutant loading or improved habitat. Restoration projects should be tracked by the coordinating agency and/or stakeholders. Recommendations for varying road and agricultural BMPs discussed in **Section 8.4** are provided below (**Table 8-2 and Table 8-3,** respectively). The recommendations provided are not an exhaustive list, and specific details of the implementation and restoration monitoring will be coordinated with local stakeholders and DEQ before future restoration activities occur. To ensure that TMDL implementation is effective in achieving full support of beneficial uses, this monitoring should be closely tied to target and supplemental indicator trend monitoring.

8.7.2.1 Road BMPs

Monitoring road sediment delivery is necessary to determine if BMPs are effective, to determine which are most effective, and to determine which practices or sites require modification to achieve water quality goals. Effectiveness monitoring should be initiated prior to implementing BMPs at treatment sites.

Monitoring actual sediment routing is difficult or prohibitively expensive. It is likely that budget constraints will influence the number of monitored sites. A detailed monitoring study design should be developed once specific restoration projects are identified. Monitoring at specific locations should continue for a period of 2-3 years after BMPs are initiated to overcome environmental variances.

Table 8-2. Monitoring Recommendations for Road BMPs

General Restoration Technique	Monitoring Recommendation	Recommended Methodology
Ditch Relief Culverts or Ditch Relief at Stream Crossings	• Place silt trap directly upslope of tributary crossing to determine mass of sediment routed to that point • Rapid inventory to document improvements and condition	• Sediment yield monitoring based on existing literature/USFS methods • Revised Washington Forest Practices Board methodology
Culvert upgrades	• Repeat road crossing inventory after implementation • Fish passage and culvert condition inventory	• Revised Washington Forest Practices Board methodology • Montana State (DNRC) culvert inventory methods
Improved Road Maintenance	• Repeat road inventory after implementation • Monitor streambed fine sediment (grid or McNeil core) and sediment routing to stream (silt traps) below specific problem areas	• Revised Washington Forest Practices Board methodology • Standard sediment monitoring methods in literature

8.7.2.2 Agricultural BMPs

Management improvements related to grazing, irrigation, and crop production have been implemented in many areas throughout the Shields River TPA. These projects often include

monitoring specific to those projects. Additional monitoring is recommended below for future improvements and projects.

Grazing BMPs function to reduce grazing pressure along streambanks and riparian areas. Recovery resulting from implementing BMPs may be reflected in improved water quality, channel narrowing, cleaner substrates, and recovery of vegetation along streambanks and riparian areas. Effectiveness monitoring for grazing BMPs should be conducted over several years, making sure to start monitoring prior to BMP implementation. If possible, monitoring reaches should be established in pastures keeping the same management as well as in those that have changed. Where grazing management includes moving livestock according to riparian use level guidelines, it is important to monitor changes within the growing season as well as over several years. Monitoring recommendations to determine seasonal and longer-term changes resulting from implementing grazing BMPs are outlined below in **Table 8-3**.

Table 8-3. Effectiveness Monitoring Recommendations for Grazing BMPs by Restoration Concern.

Recovery Concern	Monitoring Recommendations	Methodology or Source
Seasonal impacts on riparian area and streambanks	Seasonal monitoring during grazing season using riparian grazing use indicators • Streambank alteration • Riparian browse • Riparian stubble height at bank and "key area"	BDNF/BLM riparian standards (Bengeyfield and Svoboda, 1998)
Long-term riparian area recovery	• Photo points • PFC/NRCS Riparian Assessment (every 5-10 yrs) • Vegetation Survey (transects perpendicular to stream and spanning immediate floodplain) every 5-10 years o Strip transects- Daubenmire 20cm x 50cm grid or point line transects	Harrelson et al., 1994; Bauer and Burton, 1993; NRCS, 2001 Stream Assessment Protocols
Streambank stability	Greenline (i.e. near bank vegetation) including bare ground, bank stability, woody species regeneration (every 3-5 years)	Modified from Winward, 2000
Channel stability	Cross-sectional area, with % fines/ embeddedness • Channel cross-section survey • Wolman pebble count • Grid or McNeil core sample	Rosgen, 1996; Harrelson et al., 1994
Aquatic habitat condition	• Aquatic macroinvertebrate sampling • Pool quality • R1/R4 aquatic habitat survey	DEQ biomonitoring protocols; Hankin and Reeves, 1988; USFS 1997 R1R4 protocols
General stream corridor condition	EMAP/Riparian Assessment (every 5-10 yrs)	NRCS 2001 Stream Assessment Protocols; U.S. EPA 2003.

8.7.3 Standards Attainment and Watershed Trends

This type of monitoring provides a broader perspective and addresses whether water quality standards are being met or if progress is being made towards achieving the standards. Because Montana's water quality standards for sediment are narrative and targets and supplemental indicators are used to translate the standards, targets and supplemental indicators must be assessed to determine if water quality standards are being attained. DEQ will be the lead agency for developing and conducting impairment status monitoring. Other agencies or entities may work closely with DEQ to provide compatible data if interest arises. Impairment determinations are conducted by the State of Montana, but can use data from other collection sources. As mentioned above, this monitoring should be closely tied to restoration effectiveness monitoring.

8.7.3.1 Targets and Supplemental Indicators

Specific water quality targets and supplemental indicators are detailed in **Section 5.0** and **Appendix C**. These targets are intended to reflect conditions that need to be satisfied to ensure protection and/or recovery of beneficial uses. Attainment of water quality targets represent a water quality condition unimpaired for sediment, and is based on the best available data and

information regarding what constitutes attainment of sediment water quality standards in the Shields River TPA. Target indicators and values have been developed through evaluation of appropriate reference conditions, and their linkage to Montana's surface water quality standards for sediment (see **Section 4.0**). Evaluation of water quality target attainment consists of two components:

1. Evaluation of the appropriateness of established water quality targets through additional monitoring of reference conditions
2. Evaluation of target attainment

As primary water quality targets (percent surface fines, macroinvertebrates, and width-to-depth ratio) are based primarily on reference conditions thought to be appropriate for streams in the Shields River TPA, further monitoring of the target/indicator parameters in reference streams is needed to help increase confidence that the TMDL targets and supplemental indicator values best represent a translation of the narrative water quality standards for sediment (**Section 4.0**). The methods for determining reference conditions are described in **Appendix B**. As identified in Goal 3 of **Appendix H**, the SVWG would like to establish reference sites within the Shields River Watershed; DEQ will provide technical assistance.

In addition to further reference data collection for validation of established water quality targets, collection of water quality target parameter data will assist in evaluation of target attainment and impairment status. Sediment impairment determinations are based on a limited data set. Collection of primary target parameters (percent surface fines, macroinvertebrates, and width-to-depth ratio) at various locations throughout the Shields River and Potter Creek watersheds will allow a larger data set to be developed and may clarify the relationship between targets and impairment of beneficial uses. DEQ recommends that primary target parameters be collected annually at several established monitoring sites in order to evaluate attainment of water quality targets over time. The reduction of all preventable and significant anthropogenic sediment sources is a primary goal of this document. Accordingly, the TMDL implementation team will conduct 5-year inventories of these sources and will track progress towards meeting this goal.

Other parameters that may be measured for TMDL-related monitoring or impairment status monitoring include the frequency of pools and LWD, sinuosity, proper function condition assessments (PFC), algal bioassessments, and fish population dynamics (particularly for Yellowstone cutthroat trout). The siltation index is currently being revised by DEQ, but may be a good parameter to measure in the future as it is directly related to aquatic life support. Subsurface sediment may also be collected as most literature values regarding fisheries survival and fine sediment are for subsurface sediment collected with a McNeil core sampler, and existing sediment data within the Shields River TPA are for surface sediment. Although there is a relationship between the percentage of subsurface sediment and surface sediment (Platts et al. 1989), the relationship varies and DEQ is currently conducting method comparisons to determine how variable the relationship is within Montana.

8.7.3.2 Watershed Trends

Monitoring should be conducted at a watershed scale over several years to determine if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. Because whirling disease is a growing concern for YCT and its severity is associated with sediment and organic enrichment, it may be useful to compare effectiveness monitoring results in areas of BMP implementation to trends in whirling disease occurrence and severity within the watershed. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is also a long-term process. Long-term monitoring should be an understood component of any restoration effort.

Trends in water quality are difficult to define, and even more difficult to relate directly to restoration or other changes in management, due to the natural high variability in water quality conditions. Improvements in water quality or aquatic habitat resulting from restoration activities on listed streams are most likely to be evident in increases in instream flow, changes in communities and distribution of fish and other bioindicators, improvements in bank stability and riparian habitat, changes in channel cumulative width/depths, fine sediment deposition, and channel substrate embeddedness. Because targets may be adjusted in the future as the relationship between targets and beneficial use impairment is refined, values that are currently well below the target, such as fine sediment in riffles, should be included in trend monitoring. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budgetary and time constraints. Three priority watershed scale monitoring sites should be located within the Shields River Watershed (**Table 8-4**); these are existing DEQ sites located in the upper, middle, and lower part of the watershed.

Table 8-4. Sampling Locations to Monitor Watershed Trends

Site location	Latitude	Longitude
Shields River below Hill Rd bridge	46.16608	-110.569
Shields River below Indian Creek Rd bridge	45.95583	-110.634
Shields River near mouth and Livingston	45.72639	-110.464

SECTION 9.0
STAKEHOLDER AND PUBLIC COMMENTS

Stakeholder and public involvement is a component of TMDL planning efforts supported by EPA guidelines and Montana State Law. Public comment on the Shields River Watershed TMDL involved two components. First, stakeholders (including private landowners, conservation groups, and agency representatives) were kept abreast of the TMDL process through periodic meetings, and were provided opportunities to review and comment on technical documents, including a stakeholder draft. In addition, presentation of the key components of the TMDL plan at a meeting for the Upper Shields Watershed Group in Wilsall, Montana, on January 21, 2008, provided an additional forum for disseminating information on the TMDL to those living and working in the watershed. Stakeholder comments and concerns were incorporated into the next draft, the public review draft.

The second component of public involvement was the 30-day public comment period. This public review period was initiated on June 2, 2008 and extended to July 2, 2008. A public meeting on June 12, 2008 in Clyde Park, Montana provided an overview of the Shields River Watershed Water Quality Planning Framework and Sediment TMDLs and an opportunity to solicit public input and comments on the plan. This meeting and the opportunity to provide public comment on the draft document were advertised via a press release by DEQ and was included in a number of local newspapers. Copies of the main document were available at the Park County Conservation District, Livingston-Park County Public Library, and via the internet on DEQ's web page or via direct communication with the DEQ project manager.

Appendix J includes a summary of the public comments received and the DEQ response to these comments. The original comment letters are located in the project files at DEQ and may be reviewed upon request.

DEQ also provides an opportunity for public comment during the biennial review of the Montana's Integrated Water Quality Report that includes the 303(d) List. This includes public meetings and opportunities to submit comments either electronically or through traditional mail. DEQ announces the public comment opportunities through several media including press releases and the Internet.

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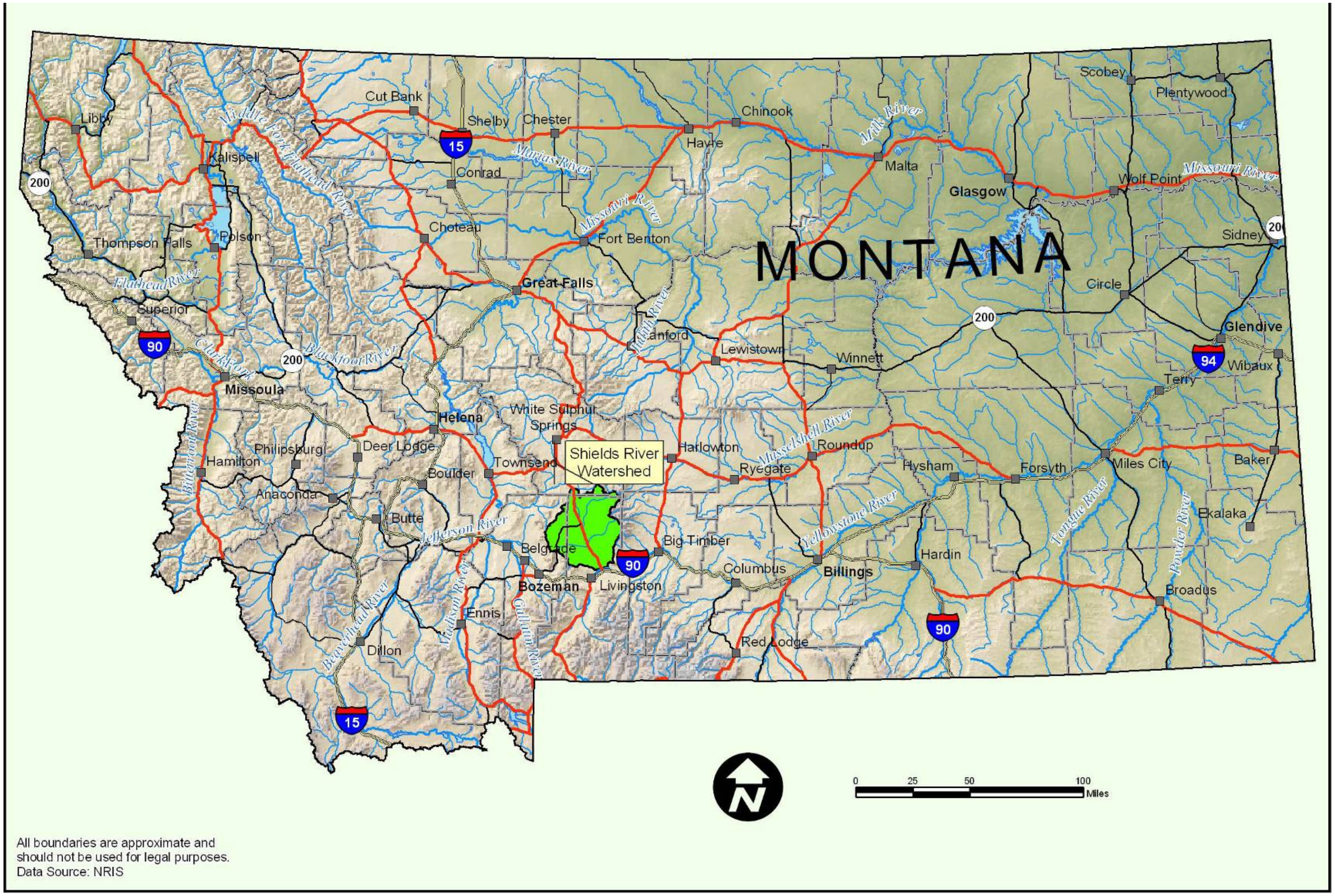
ACRONYMS

Acronym	Meaning
AGNPS	Agricultural Nonpoint Source Model
ANSWERS	Areal Nonpoint Source Watershed Environment Response Simulation Model
ARM	Administrative Rules of Montana
BDNF	Beaverhead-Deerlodge National Forest
BEHI	Bank Erodibility Hazard Index
BER	Board of Environmental Review
BLM	Bureau of Land Management, United States
BMP	Best Management Practice
CBM	Coal bed methane
CD	Conservation District
CFR	Code of Federal Regulations
cfs	Cubic Feet Per Second
CWA	Clean Water Act
CWMA	Cooperative Weed Management Area
DEM	Digital Elevation Models
DEQ	Department of Environmental Quality, Montana
DEQ-7	Circular DEQ-7, Montana Water Quality Standards
DNRC	Department of Natural Resources and Conservation
DOQQ	USGS Digital Orthophoto Quarter Quad
EPIC	Erosion Productivity Impact Calculator
EPA	Environmental Protection Agency
FWP	Fish Wildlife and Parks, Montana Department of
GIS	Geographic Information Systems
GNF	Gallatin National Forest
GWLF	Generalized Watershed Loading Functions
HUC	Hydrologic Unit Code
LA	Load Allocation
LS	length and slope
LWD	Large Woody Debris
MAES	Montana Agricultural Extension Service
MCA	Montana Code Annotated
MDEQ	Montana Department of Environmental Quality
MMI	Multi-Metric Index
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
MSU	Montana State University
NAIP	National Agriculture Imagery Program
NBS	Near Bank Stress
NF	National Forest
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source Pollution

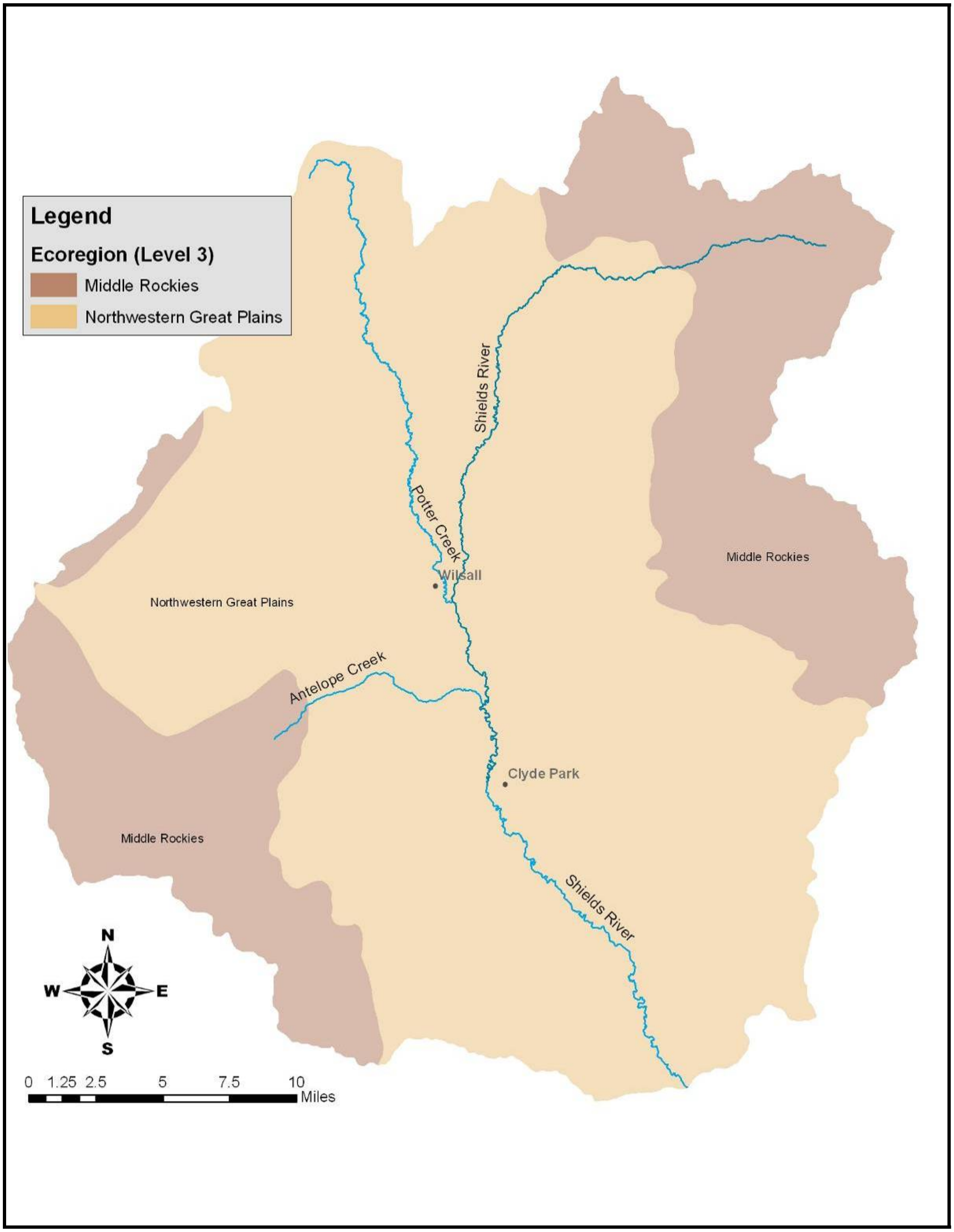
NRCS .... Natural Resource Conservation Service
NRIS .... Natural Resource Information Services
O/E .... Observed/Expected
PFC .... Proper Functioning Condition (Riparian)
PRISM........ Parameter-elevation Regressions on Independent Slopes Model
RIVPACS........ River Invertebrate Prediction and Classification System
SCAS........ Spatial Climate Analysis Service
SCD........ Sufficient Credible Data
SCS .... Soil Conservation Service
SDR........ Sediment Delivery Ratio
SMZ .... Streamside Management Zones
SNOTEL .... Snowpack Telemetry
STATSGO........ State Soil Geographic Database
SSURGO........ Soil Survey Geographic Database
SVWG........ Shields Valley Watershed Group
SWAT .... Soil Water Assessment Tool
TIGER........ Topologically Integrated Geographic Encoding and Referencing
TM .... Thematic Mapper
TMDL .... Total Maximum Daily Loads
TPA .... TMDL Planning Area
TSS........ Total Suspended Solids
UAA .... Use Attainability Assessment
USDA .... United State Department of Agriculture
USFS .... United States Forest Service
USGS .... United States Geological Survey
USLE........ Universal Soil Loss Equation
VFS .... Vegetated Filter Strips
VM .... Vegetation Management
W/D Ratio .... Width to Depth Ratio
WARSEM .... Washington Road Surface Erosion Model
WQA .... Water Quality Act
WLA .... Waste Load Allocation
WQB-7........ Circular DEQ-7, Montana Water Quality Standards
WQPB .... Water Quality Planning Bureau
WQS........ Water Quality Standards
WRP .... Watershed Restoration Plans
YCT........ Yellowstone cutthroat trout

Appendix A

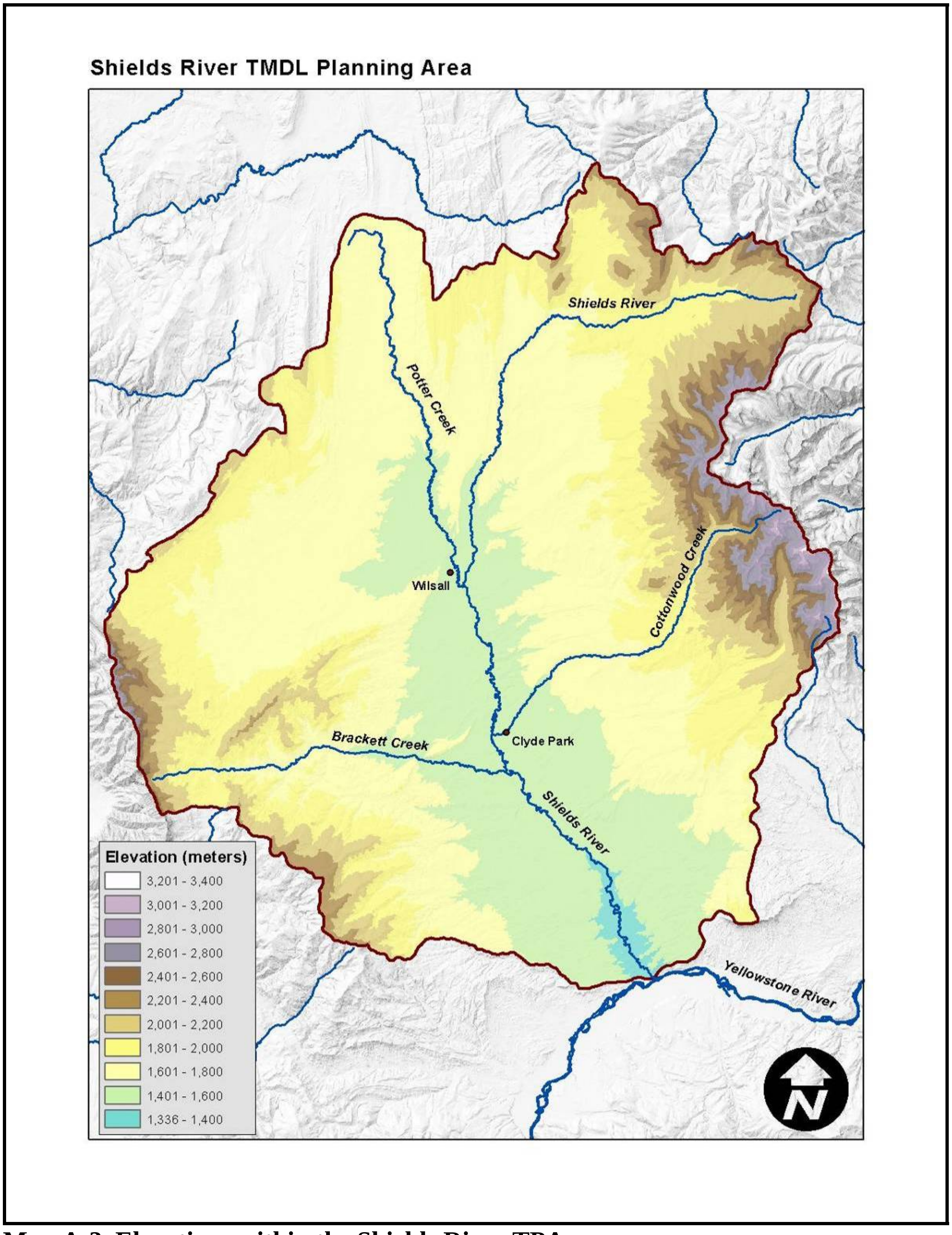
Maps



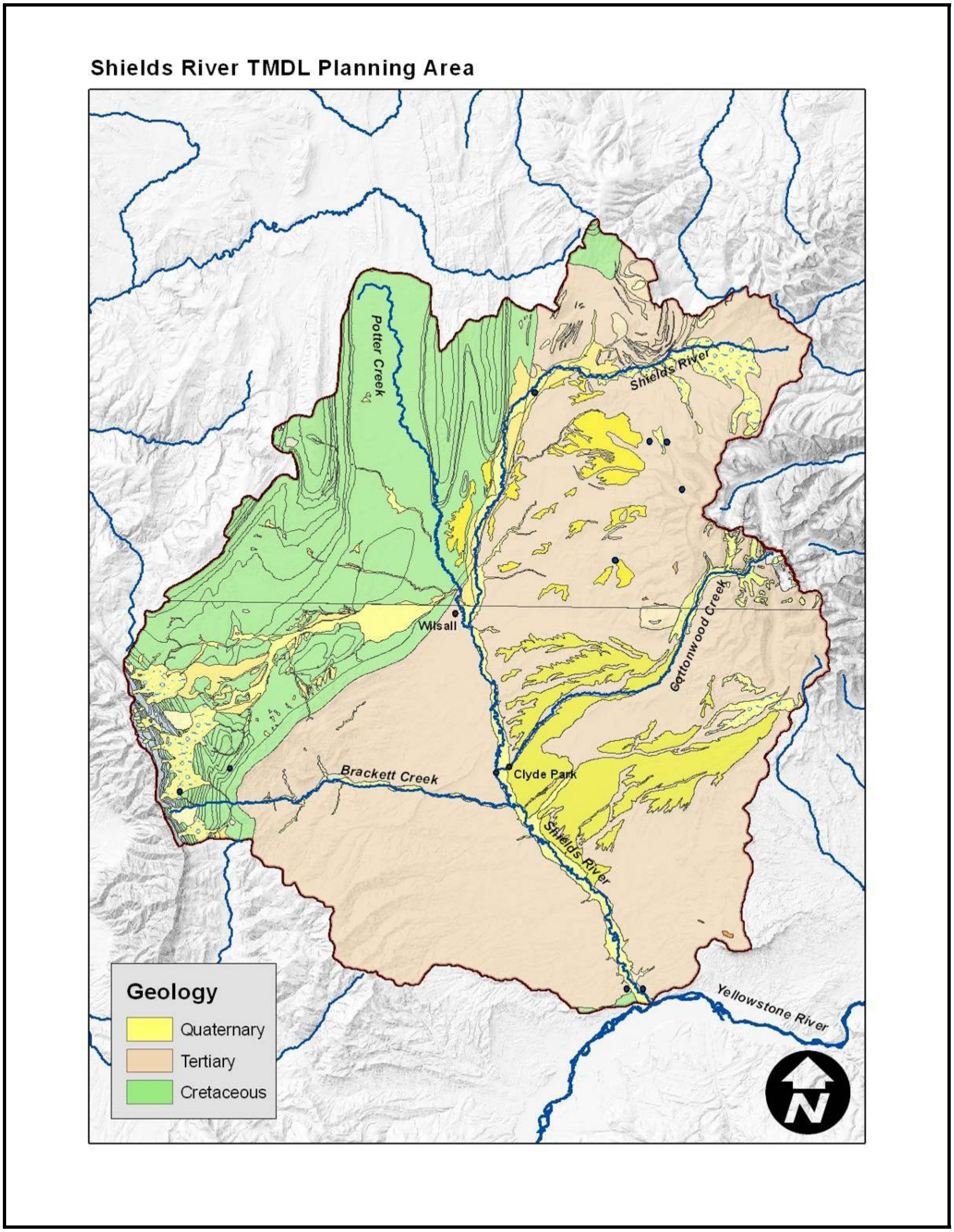
Map A-1. Location of the Shields River TPA



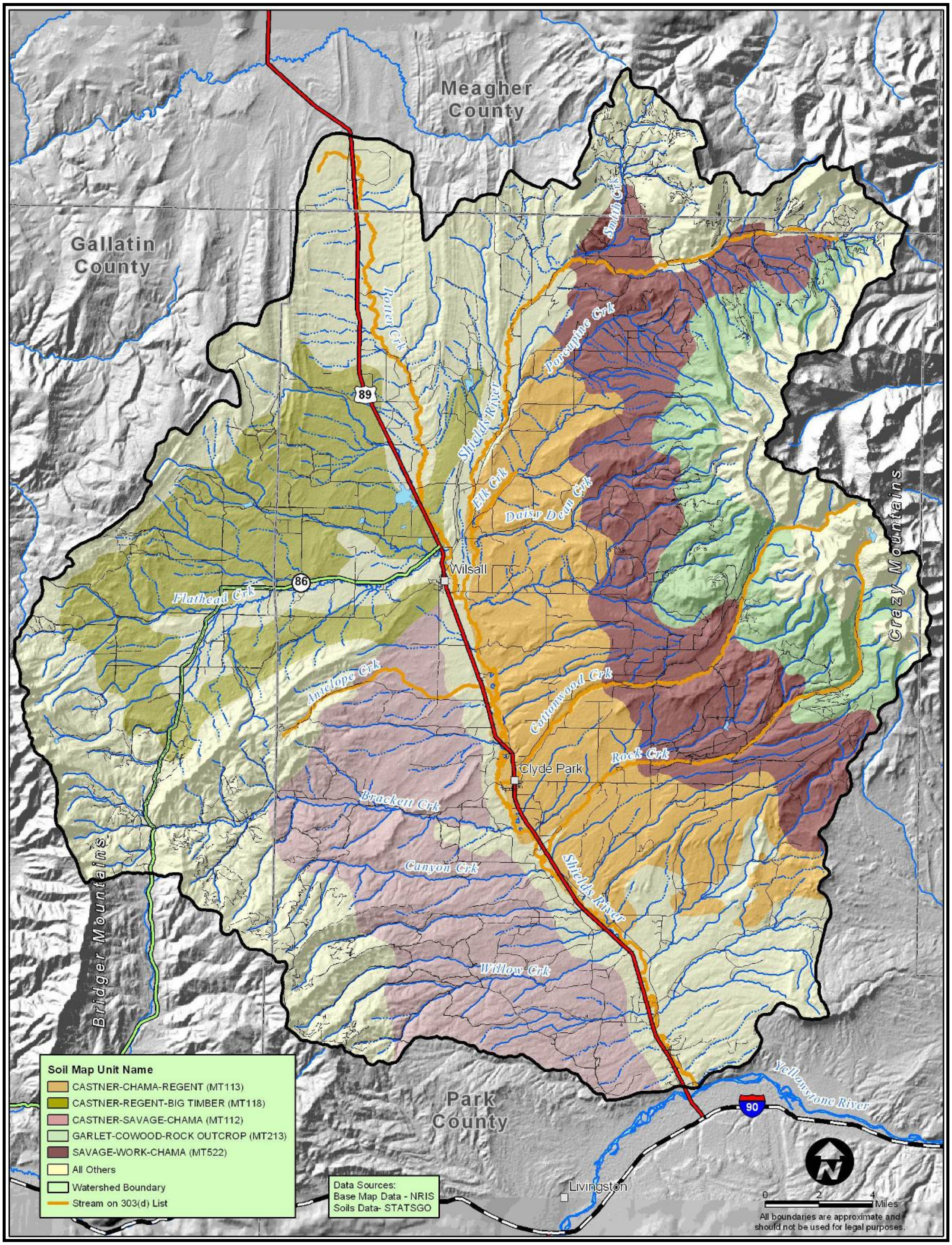
Map A-2. Ecoregion Level 3 Boundaries within the Shields River TPA



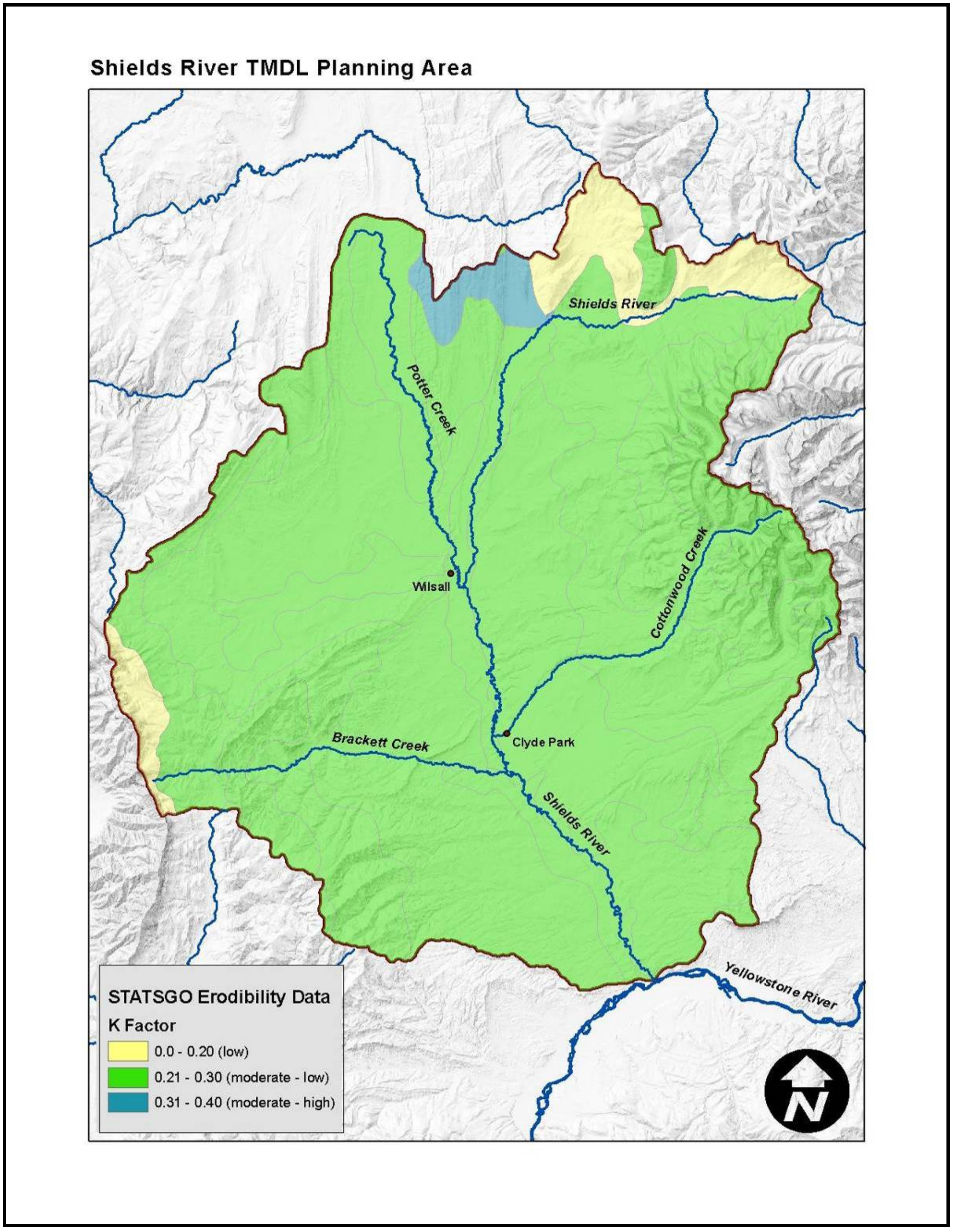
Map A-3. Elevations within the Shields River TPA



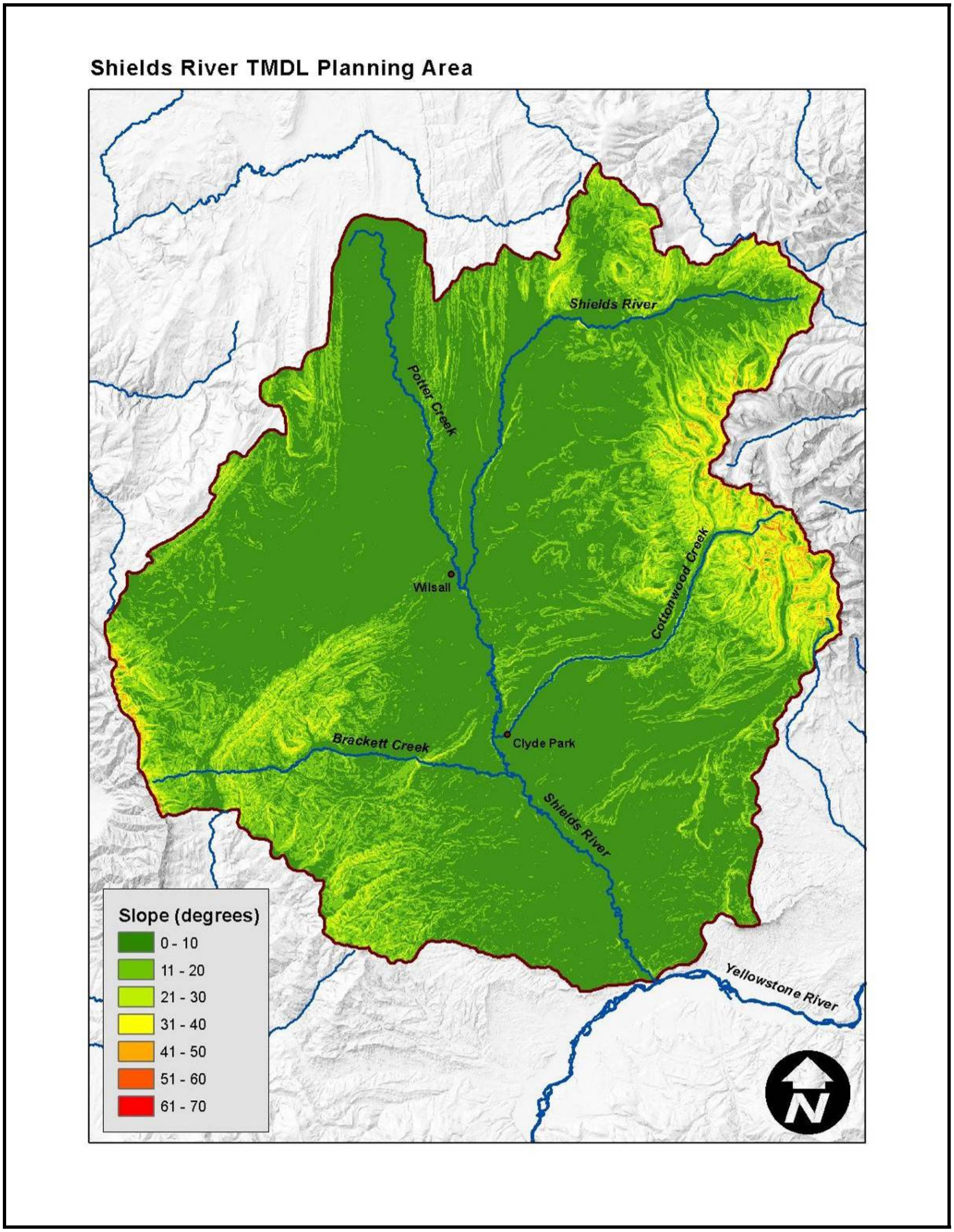
Map A-4. Geology of the Shields River TPA



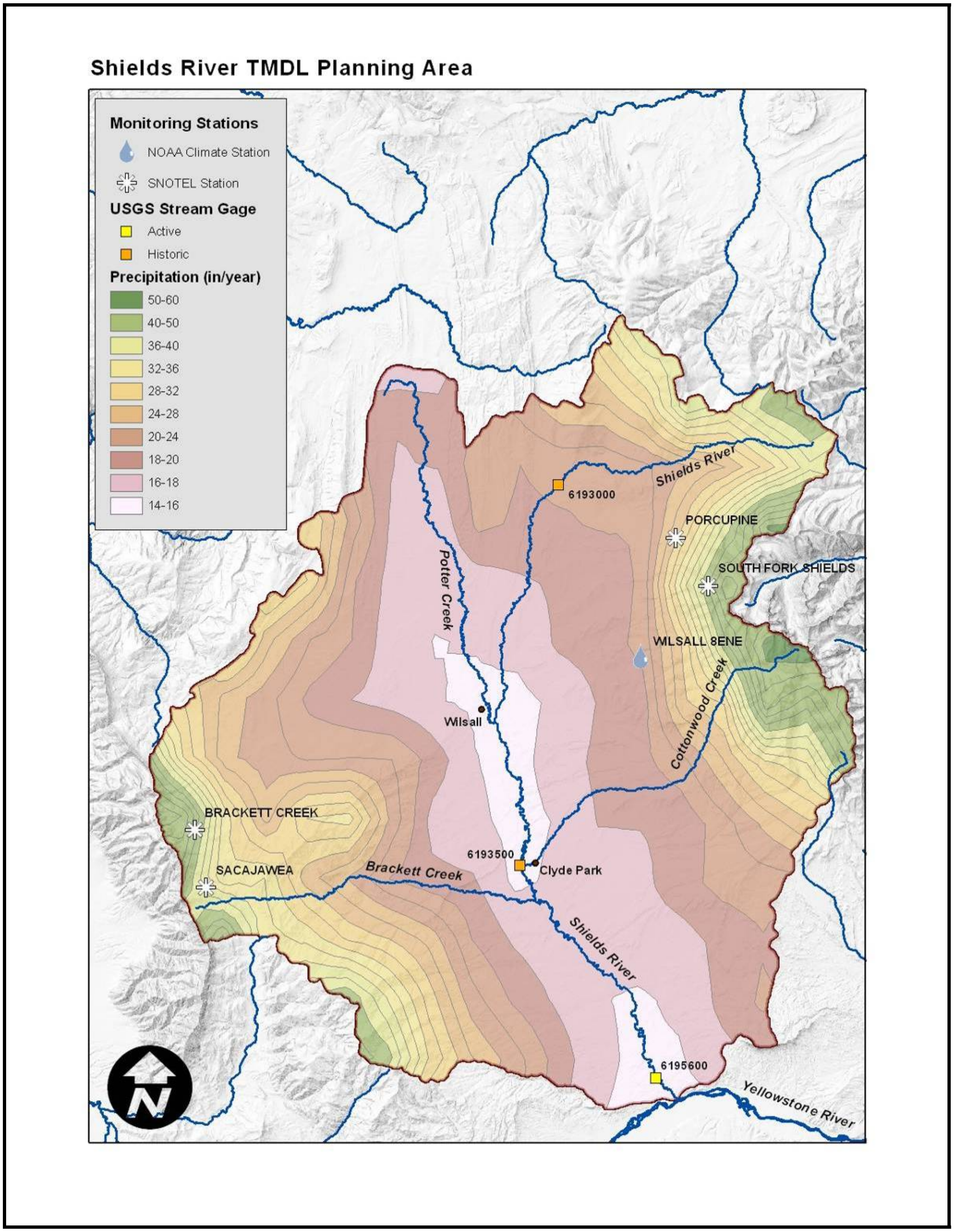
Map A-5. STATSGO Soils Units within the Shields River TPA



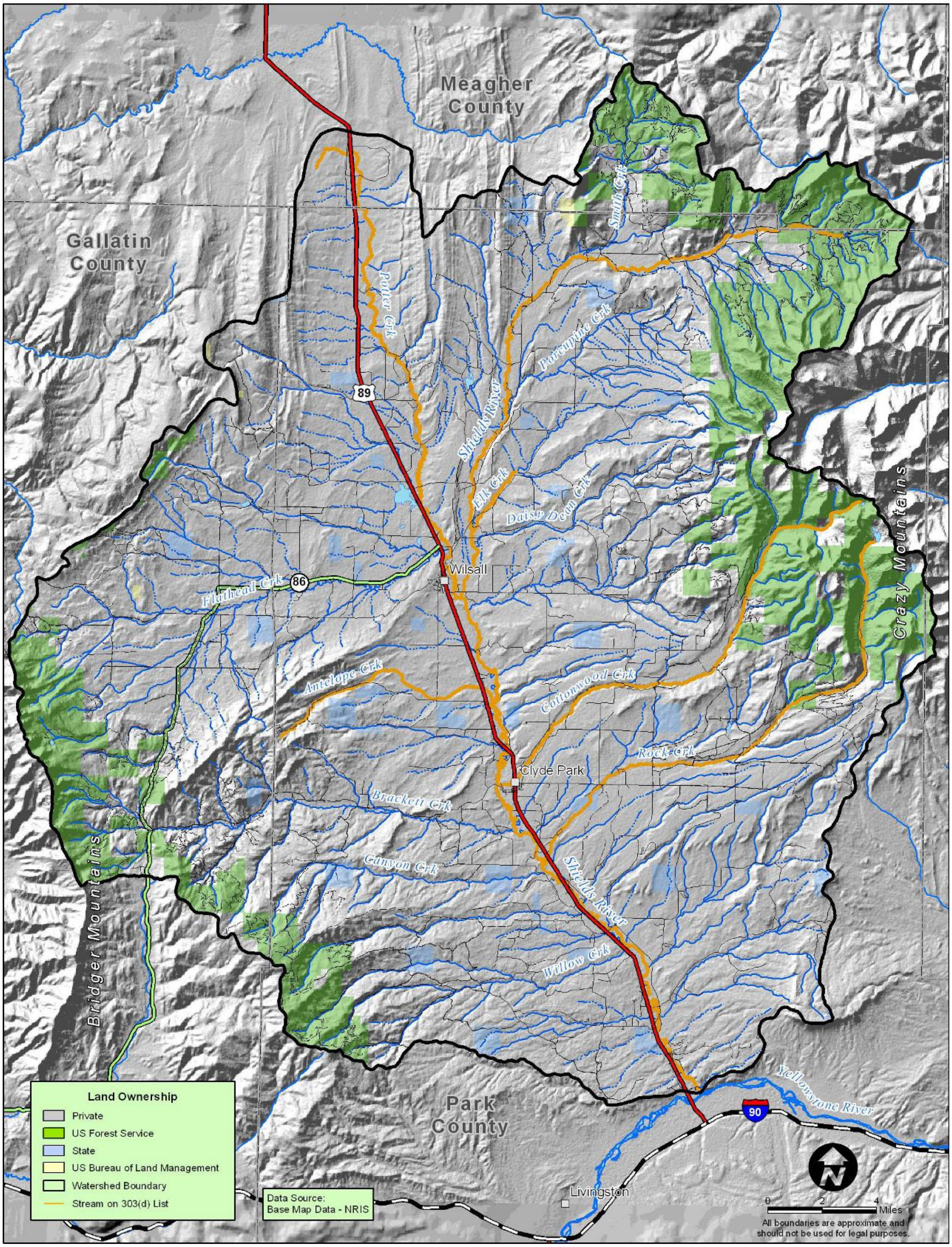
Map A-6. Soils Erodibility in the Shields River TPA



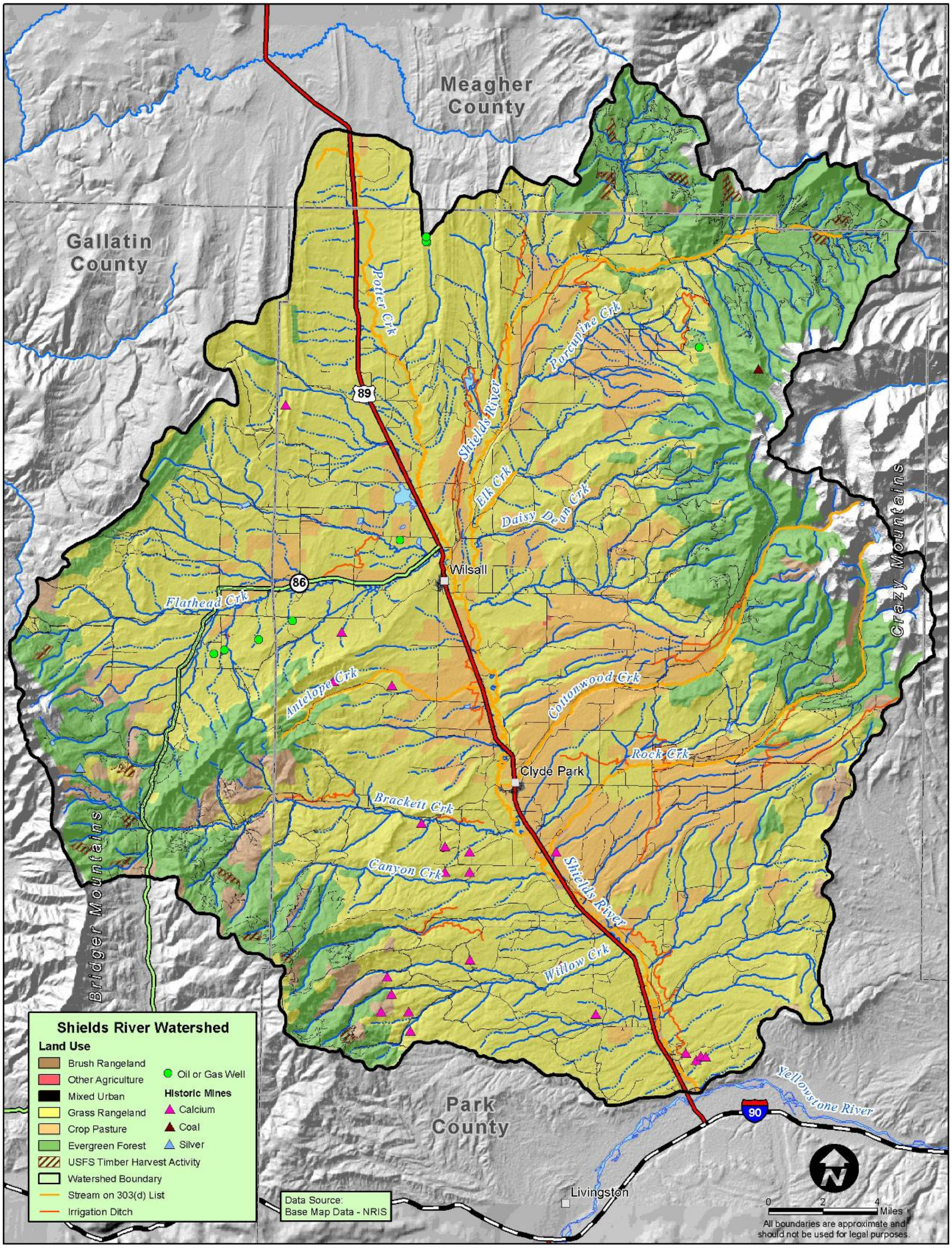
Map A-7. Slope throughout the Shields River TPA



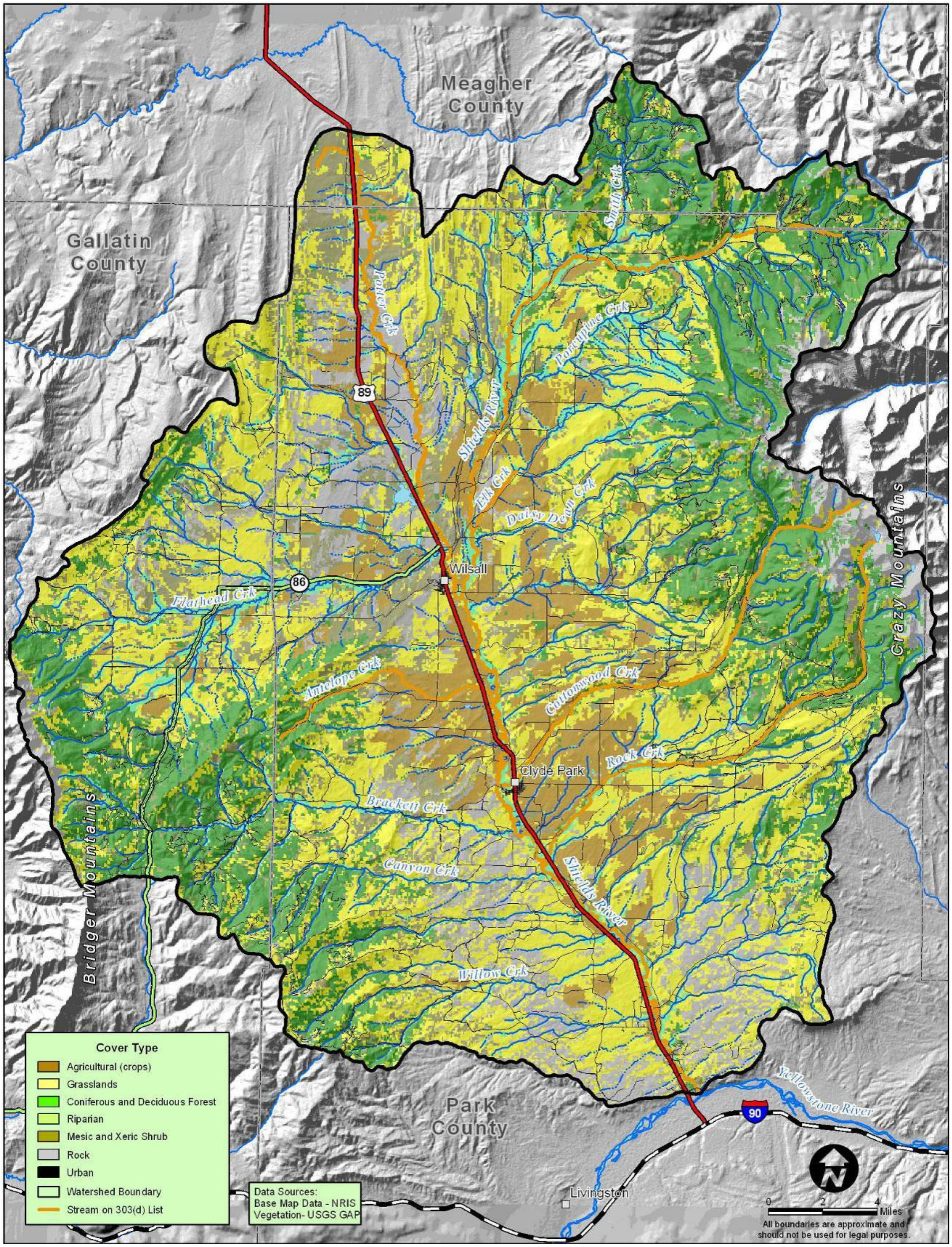
Map A-8. PRISM Climate Data for the Shields River TPA



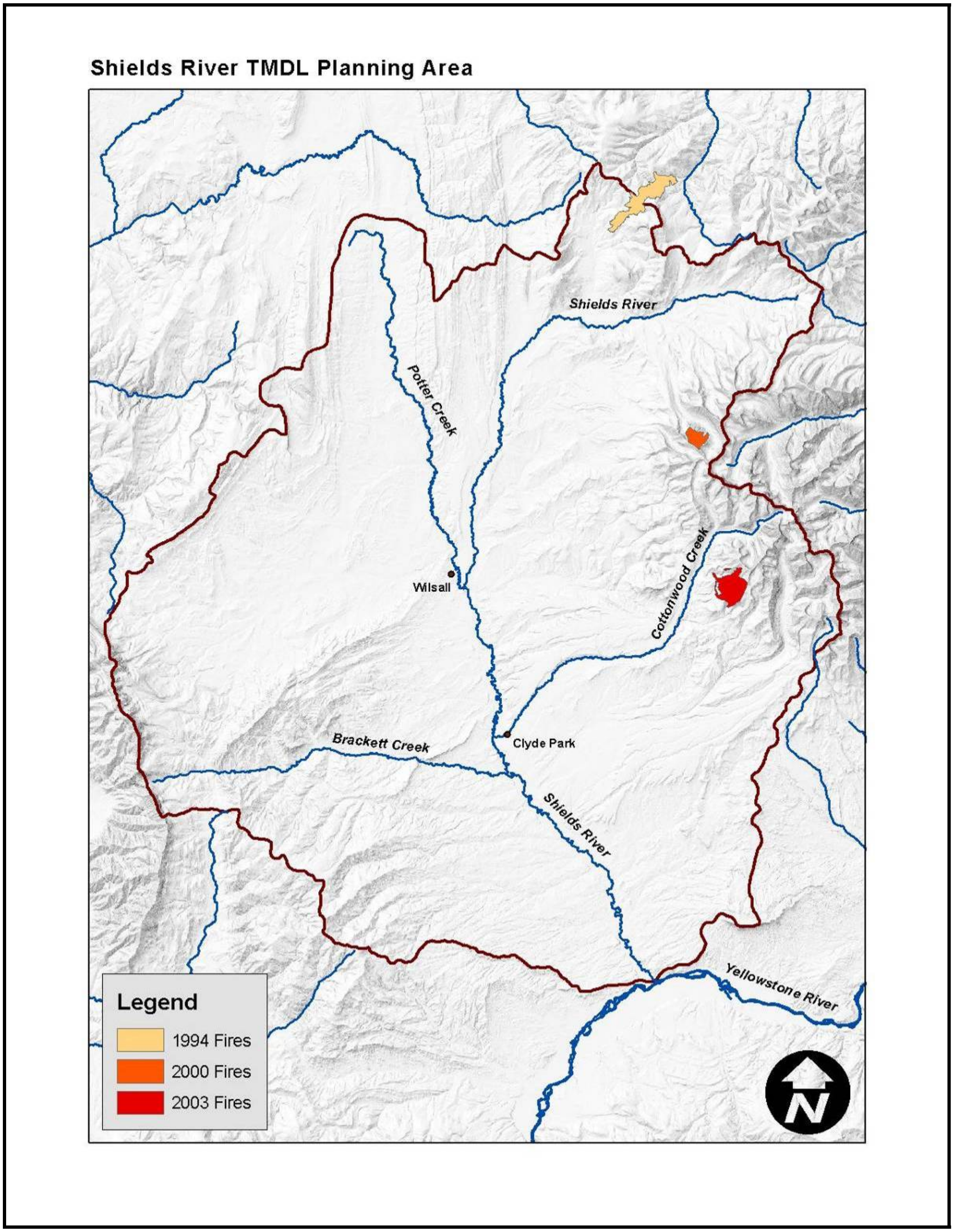
Map A-9. Land Ownership within the Shields River TPA



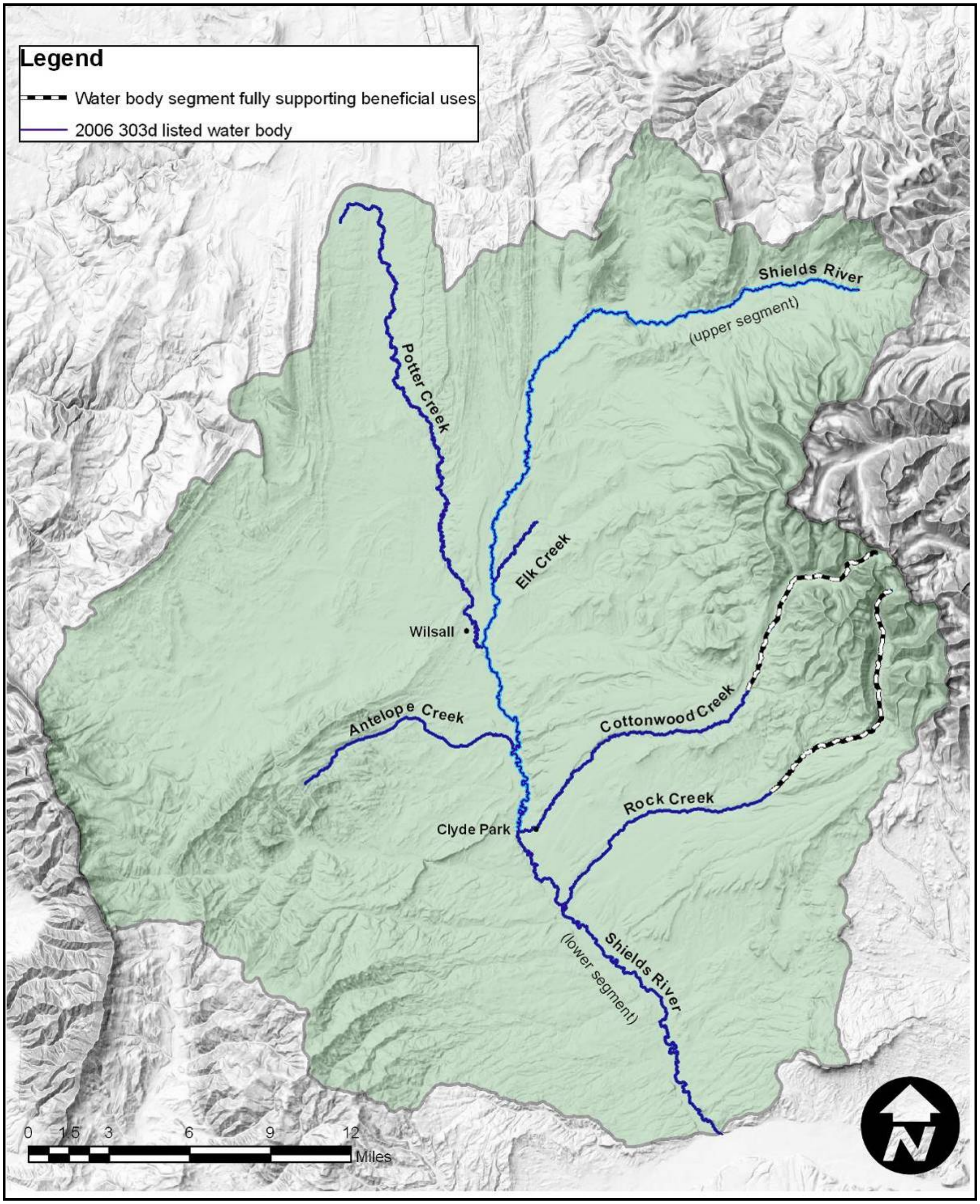
Map A-10. Land Use Classes within the Shields River TPA



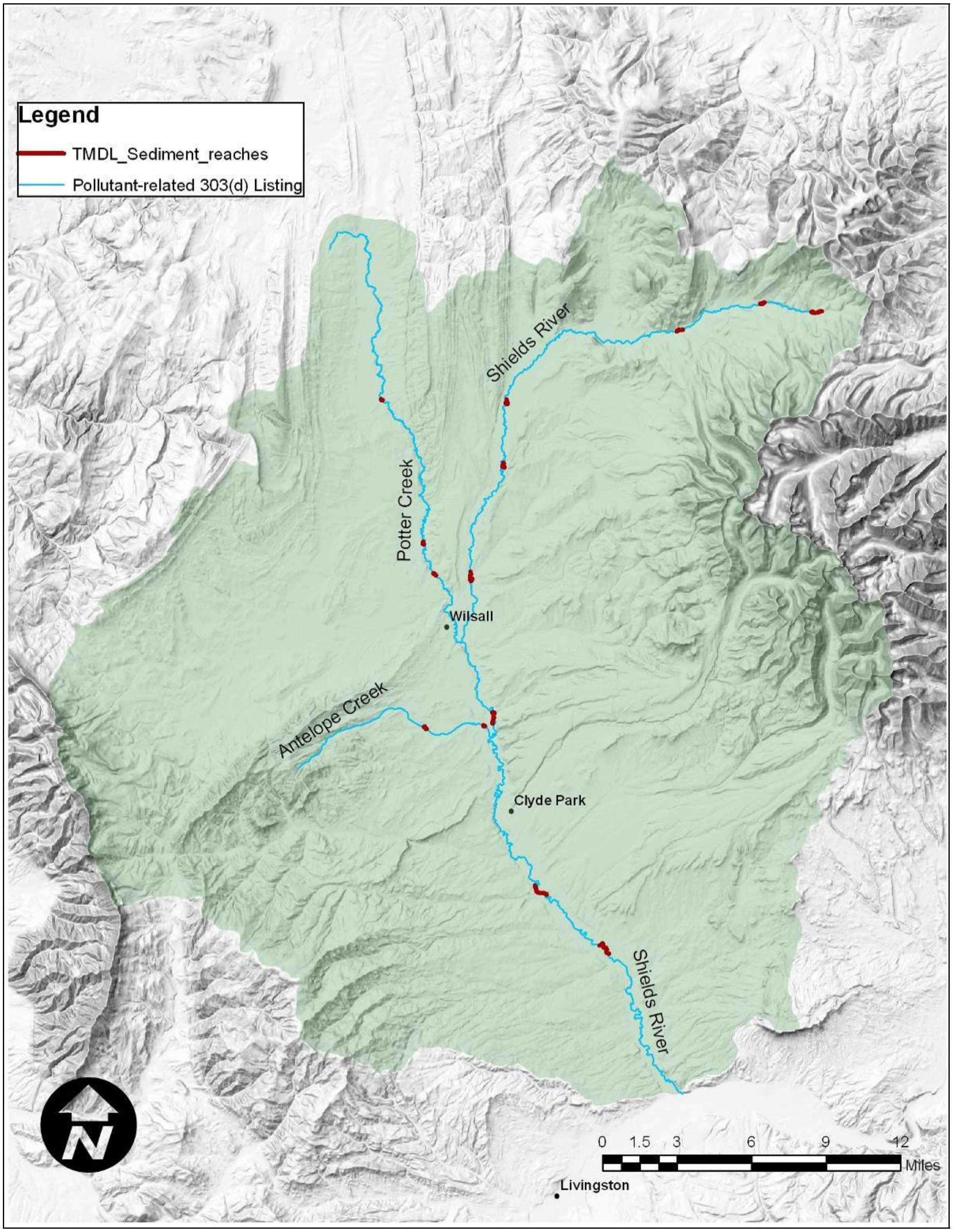
Map A-11. Vegetative Cover Types within the Shields River TPA



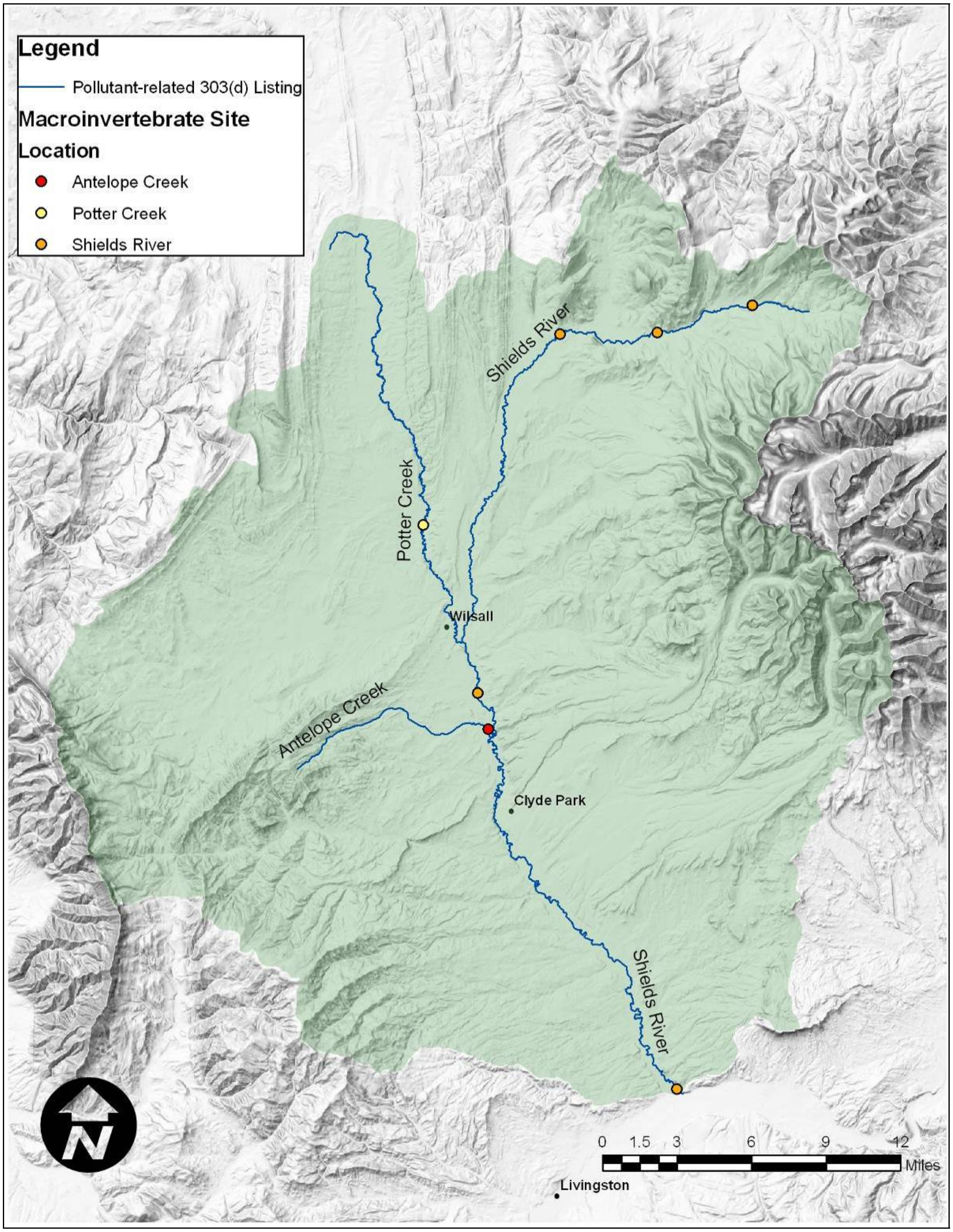
Map A-12. Historical Fires within the Shields River TPA



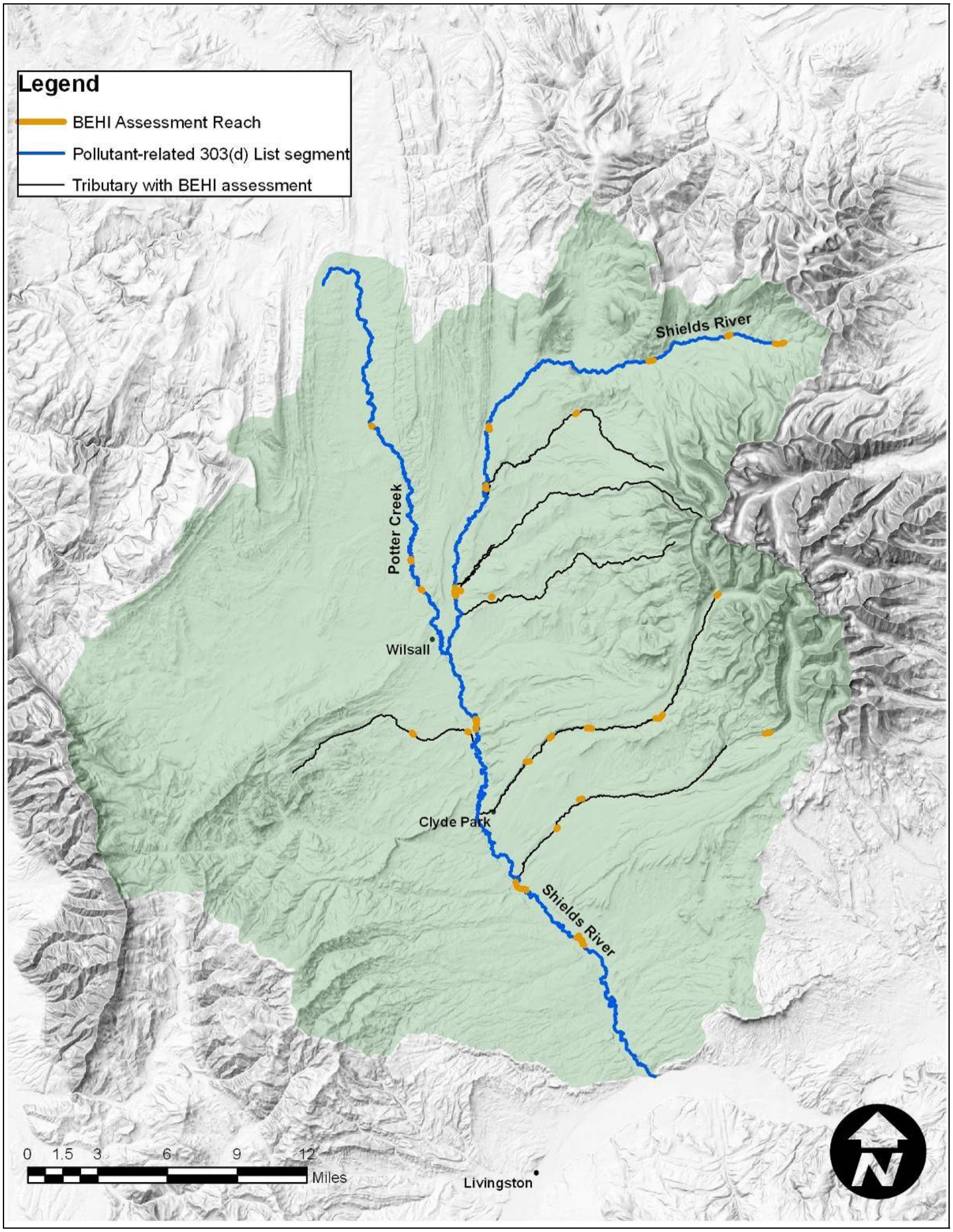
Map A-13. Water Bodies within the Shields TPA on the 2006 303(d) List



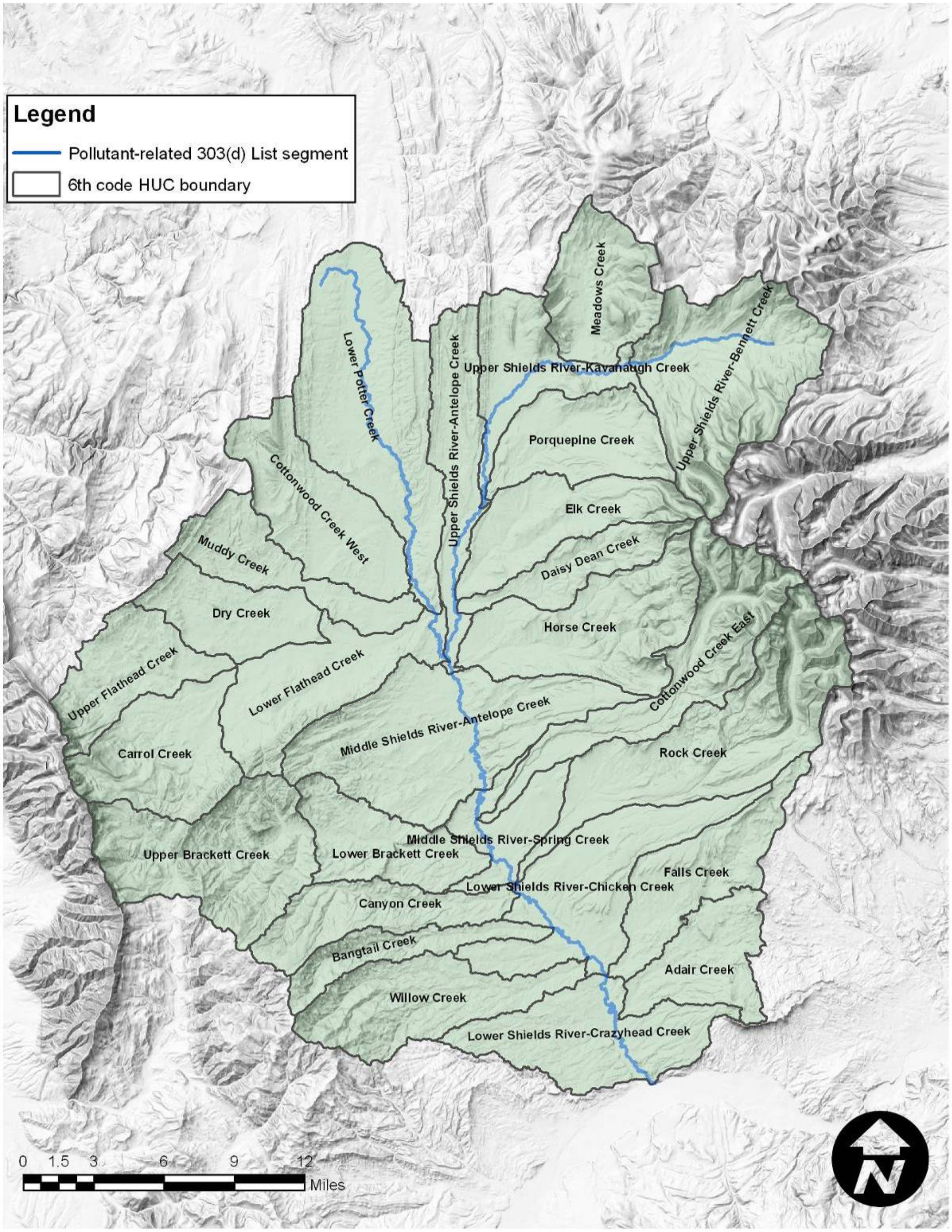
Map A-14. Sediment and Habitat Assessment Reaches for 2004 Sampling



Map A-15. Macroinvertebrate Sampling Sites



Map A-16. Reaches with Bank Erosion (BEHI) Measurements Conducted in 2004



Map A-17. 6th Code HUC Boundaries for the Shields River TPA

APPENDIX B
REGULATORY FRAMEWORK AND REFERENCE CONDITION APPROACH

This appendix presents details about applicable Montana Water Quality Standards (WQS) and the general and statistical methods used for development of reference conditions.

B.1 TMDL Development Requirements

Section 303 of the Federal CWA and the Montana WQA (Section 75-5-703) requires development of TMDLs for impaired water bodies that do not meet Montana WQS. Although water bodies can become impaired from pollution (e.g. flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, and metals), the CWA and Montana State Law (75-5-703) both require TMDL development for waters impaired only by pollutants. Section 303 also requires states to submit a list of impaired water bodies to EPA every two years. Prior to 2004, EPA and DEQ referred to this list as the 303(d) List.

Since 2004, EPA has requested that states combine the 303(d) List with the 305(b) report containing an assessment of Montana's water quality and its water quality programs. EPA refers to this new combined 303(d)/305(b) report as the Integrated Water Quality Report. The 303(d) List also includes identification of the probable cause(s) of the water quality impairment problems (e.g. pollutants such as metals, nutrients, sediment or temperature), and the suspected source(s) of the pollutants of concern (e.g. various land use activities). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each water body is used for consistency; the actual methodology is identified in DEQ's Water Quality Assessment Process and Methods (DEQ 2006b). This methodology was developed via a public process and was incorporated into the EPA-approved 2000 version of the 305(b) report (now also referred to as the Integrated Report).

Under Montana State Law, an "impaired water body" is defined as a water body or stream segment for which sufficient credible data show that the water body or stream segment is failing to achieve compliance with applicable WQS (Montana Water Quality Act; Section 75-5-103(11)). A "threatened water body" is defined as a water body or stream segment for which sufficient credible data and calculated increases in loads show that the water body or stream segment is fully supporting its designated uses but threatened for a particular designated use because of either (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana WQA; Section 75-5-103(31)). State Law and Section 303 of the CWA require states to develop all necessary TMDLs for impaired or threatened water bodies. There are no threatened water bodies within the Shields TPA.

A TMDL is a pollutant budget for a water body identifying the maximum amount of the pollutant that a water body can assimilate without causing applicable WQS to be exceeded. TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in

units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources and must incorporate a margin of safety and consider influences of seasonality on analysis and compliance with WQS.

To satisfy the Federal CWQ and Montana State Law, TMDLs will be developed for each water body-pollutant combination identified on Montana's 303(d) List of impaired or threatened waters in the Shields River TPA. State Law (Administrative Rules of Montana 75-5-703(8)) also directs Montana DEQ to "...support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for water bodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or local regulations.

B.2 Applicable Water Quality Standards

WQS include the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a non-degradation policy that protects the high quality of a waterbody. The ultimate goal of this TMDL document, once implemented, is to ensure that all designated beneficial uses are fully supported and all standards are met. The WQS form the basis for impairment determinations and development of numeric values used for TMDL targets and other use support objectives. This section provides a summary of the applicable WQS for sediment and other conditions limiting cold-water fish as identified in **Table B-2**.

B.2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a waterbody based on the potential of the waterbody to support those uses. Designated Uses or Beneficial Uses are simple narrative descriptions of water quality expectations or water quality goals. There are a variety of "uses" of state waters including growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana WQA directs the BER (i.e., the state) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses (ARM 17.30.607-616) and to adopt standards to protect those uses (ARM 17.30.620-670).

Montana, unlike many other states, uses a watershed based classification system with some specific exceptions. As a result, *all* waters of the state are classified and have designated uses and supporting standards. All classifications have multiple uses and in only one case (A-Closed) is a specific use (drinking water) given preference over the other designated uses. Some waters may not actually be used for a specific designated use, for example as a public drinking water supply; however, the quality of that waterbody must be maintained suitable for that designated use. When natural conditions limit or preclude a designated use, permitted point source discharges or non-point source activities or pollutant discharges may not make the natural conditions worse.

Modification of classifications or standards that would lower a water's classification or a standard (i.e., B-1 to a B-3), or removal of a designated use because of natural conditions can

only occur if the water was originally misclassified. All such modifications must be approved by the BER, and are undertaken via a Use Attainability Analysis (UAA) that must meet EPA requirements (40 CFR 131.10(g), (h) and (j)). The UAA and findings presented to the BER during rulemaking must prove that the modification is correct and all existing uses are supported. An existing use cannot be removed or made less stringent.

Descriptions of Montana's surface water classifications and designated beneficial uses are presented in **Table B-1**. All water bodies within the Shields River TPA are classified as B-1 (17.30.607). Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply (17.30.623[1]).

Table B-1. Montana Surface Water Classifications and Designated Beneficial Uses

Classification	Designated Uses
A-CLOSED CLASSIFICATION:	Waters classified A-Closed are to be maintained suitable for drinking, culinary and food processing purposes after simple disinfection.
A-1 CLASSIFICATION:	Waters classified A-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities.
B-1 CLASSIFICATION:	Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-2 CLASSIFICATION:	Waters classified B-2 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-3 CLASSIFICATION:	Waters classified B-3 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-1 CLASSIFICATION:	Waters classified C-1 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-2 CLASSIFICATION:	Waters classified C-2 are to be maintained suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-3 CLASSIFICATION:	Waters classified C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agriculture and industrial water supply.
I CLASSIFICATION:	The goal of the State of Montana is to have these waters fully support the following uses: drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

B.2.2 Standards

In addition to the Use Classifications described above, Montana's WQS include numeric and narrative criteria as well as a nondegradation policy.

Numeric surface WQS have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular WQB-7 (DEQ 2006a). The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., life long) exposures as well as through direct contact such as swimming.

The numeric aquatic life standards include chronic and acute values that are based on extensive laboratory studies including a wide variety of potentially affected species, a variety of life stages and durations of exposure. Chronic aquatic life standards are protective of long-term exposure to a parameter. The protection afforded by the chronic standards includes detrimental effects to reproduction, early life stage survival and growth rates. In most cases the chronic standard is more stringent than the corresponding acute standard. Acute aquatic life standards are protective of short-term exposures to a parameter and are not to be exceeded.

High quality waters are afforded an additional level of protection by the nondegradation rules (ARM 17.30.701 et. seq.,) and in statute (75-5-303 MCA). Changes in water quality must be "non-significant" or an authorization to degrade must be granted by the Department. However under no circumstance may standards be exceeded. It is important to note that, waters that meet or are of better quality than a standard are high quality for that parameter, and nondegradation policies apply to new or increased discharges to that the waterbody.

Narrative standards have been developed for substances or conditions for which sufficient information does not exist to develop specific numeric standards. The term "Narrative Standards" commonly refers to the General Prohibitions in ARM 17.30.637 and other descriptive portions of the surface WQS. The General Prohibitions are also called the "free from" standards; that is, the surface waters of the state must be free from substances attributable to discharges, including thermal pollution, that impair the beneficial uses of a waterbody. Uses may be impaired by toxic or harmful conditions (from one or a combination of parameters) or conditions that produce undesirable aquatic life. Undesirable aquatic life includes bacteria, fungi, and algae.

The standards applicable to sediment, which is the only pollutant addressed within this document, are summarized below. In addition to the below sediment standards, the beneficial use support standard (17.30.623[1]) for a B-1 Stream, as defined above, can apply to other conditions, often linked to pollution, limiting aquatic life. These other conditions can include impacts from dewatering/flow alterations or impacts from habitat modifications not linked directly to excess sediment concentrations.

Sediment
Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative criteria identified in **Table B-2**. The relevant narrative criteria do not allow for harmful or other undesirable conditions related to increases above naturally occurring levels or from

discharges to state surface waters. This is interpreted to mean that water quality goals should strive toward a reference condition that reflects a waterbody's greatest potential for water quality given current and historic land use activities where all reasonable land, soil, and water conservation practices have been applied and resulting conditions are not harmful, detrimental, or injurious to beneficial uses (see definitions in **Table B-2**).

Table B-2: Applicable Rules for Sediment Related Pollutants.

Rule(s)	Standard
17.30.623(2)	No person may violate the following specific WQS for waters classified B-1.
17.30.623(2)(f)	No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except a permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.
17.30.623(2)(d)	The maximum allowable increase above naturally occurring turbidity is: five nephelometric turbidity units except as permitted in 75-5-318, MCA.
17.30.637(1)	State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will.
17.30.637(1)(a)	Settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines.
17.30.637(1)(d)	Create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.
17.30.602(17)	"Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied.
17.30.602(21)	"Reasonable land, soil, and water conservation practices" means methods, measures, or practices that protect present and reasonably anticipated beneficial uses. These practices include but are not limited to structural and nonstructural controls and operation and maintenance procedures. Appropriate practices may be applied before, during, or after pollution-producing activities.
17.30.602.(28)	"Sediment" means solid material settled from suspension in a liquid; mineral or organic solid material that is being transported or has been moved from its site of origin by air, water or ice and has come to rest on the earth's surface, either above or below sea level; or inorganic or organic particles originating from weathering, chemical precipitation or biological activity.

It should be noted that reasonable land, soil, and water conservation practices are not always accomplished by using BMPs (DEQ 2006b). BMPs are land management practices that provide a degree of protection for water quality, but they may not be sufficient to achieve compliance with WQS and protect beneficial uses. Therefore, reasonable land, soil, and water conservation practices generally include BMPs, but additional conservation practices may be required to achieve compliance with WQS and restore beneficial uses.

B.3 Reference Conditions

B.3.1 Reference Conditions as Defined in DEQ's Standard Operating Procedure for Water Quality Assessment (2006b)

DEQ uses the reference condition to evaluate compliance with many of the narrative WQS. The term "reference condition" is defined as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a waterbody's greatest potential for water quality given historic land use activities.

DEQ applies the reference condition approach for making beneficial use-support determinations for certain pollutants (such as sediment) that have specific narrative standards. All classes of waters are subject to the provision that there can be no increase above naturally occurring concentrations of sediment and settleable solids, oils, or floating solids sufficient to create a nuisance or render the water harmful, detrimental, or injurious. These levels depend on site-specific factors, so the reference conditions approach is used.

Also, Montana WQS do not contain specific provisions addressing nutrients (nitrogen and phosphorous), or detrimental modifications of habitat or flow. However, these factors are known to adversely affect beneficial uses under certain conditions or combination of conditions. The reference conditions approach is used to determine if beneficial uses are supported when nutrients, flow, or habitat modifications are present.

Waterbodies used to determine reference condition are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. Reference condition also does not reflect an effort to turn the clock back to conditions that may have existed before human settlement, but is intended to accommodate natural variations in biological communities, water chemistry, etc. due to climate, bedrock, soils, hydrology, and other natural physiochemical differences. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity. Therefore, reference conditions should reflect minimum impacts from human activities. It attempts to identify the potential condition that could be attained (given historical land use) by the application of reasonable land, soil, and water conservation practices. DEQ realizes that presettlement water quality conditions usually are not attainable.

Comparison of conditions in a waterbody to reference waterbody conditions must be made during similar season and/or hydrologic conditions for both waters. For example, the Total Suspended Solids (TSS) of a stream at base flow during the summer should not be compared to the TSS of reference condition that would occur during a runoff event in the spring. In addition, a comparison should not be made to the lowest or highest TSS values of a reference site, which represent the outer boundaries of reference conditions.

The following methods may be used to determine reference conditions:

Primary Approach

- Comparing conditions in a waterbody to baseline data from minimally impaired waterbodies that are in a nearby watershed or in the same region having similar geology, hydrology, morphology, and/or riparian habitat.
- Evaluating historical data relating to condition of the waterbody in the past.
- Comparing conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired segment of the same stream.

Secondary Approach

- Reviewing literature (e.g. a review of studies of fish populations, etc., that were conducted on similar waterbodies that are least impaired.
- Seeking expert opinion (e.g. expert opinion from a regional fisheries biologist who has a good understanding of the waterbody's fisheries health or potential).
- Applying quantitative modeling (e.g. applying sediment transport models to determine how much sediment is entering a stream based on land use information, etc.).

DEQ uses the primary approach for determining reference condition if adequate regional reference data are available and uses the secondary approach to estimate reference condition when there are no regional data. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

B.3.2 Use of Statistics for Developing Reference Values or Ranges

Reference value development must consider natural variability as well as variability that can occur as part of field measurement techniques. Statistical approaches are commonly used to help incorporate variability. One statistical approach is to compare stream conditions to the mean (average) value of a reference data set to see if the stream condition compares favorably to this value or falls within the range of one standard deviation around the reference mean. The use of these statistical values assumes a normal distribution, whereas water resources data tend to have a non-normal distribution (Hensel and Hirsch 1995). For this reason, another approach is to compare stream conditions to the median value of a reference data set to see if the stream condition compares favorably to this value or falls within the range defined by the 25^{th} and 75^{th} percentiles of the reference data. This is a more realistic approach than using one standard deviation since water quality data often include observations considerably higher or lower than most of the data. Very high and low observations can have a misleading impact on the statistical summaries if a normal distribution is incorrectly assumed, whereas statistics based on non-normal distributions are far less influenced by such observations.

Figure B-1 is an example boxplot type presentation of the median, 25^{th} and 75^{th} percentiles, and minimum and maximum values of a reference data set. In this example, the reference stream results are stratified by two different stream types. Typical stratifications for reference stream data may include Rosgen stream types, stream size ranges, or geology. If the parameter being measured is one where low values are undesirable and can cause harm to aquatic life, then measured values in the potentially impaired stream that fall below the 25^{th} percentile of reference data are not desirable and can be used to indicate impairment. If the parameter being measured is

one where high values are undesirable, then measured values above the 75th percentile can be used to indicate impairment.

The use of a non-parametric statistical distribution for interpreting narrative WQS or developing numeric criteria is consistent with EPA guidance for determining nutrient criteria (EPA 2000). Furthermore, the selection of the applicable 25th or 75th percentile values from a reference data set is consistent with ongoing DEQ guidance development for interpreting narrative WQS where it is determined that there is “good” confidence in the quality of the reference sites and resulting information (DEQ 2004). If it is determined that there is only a “fair” confidence in the quality of the reference sites, then the 50th percentile or median value should be used, and if it is determined that there is “very high” confidence, then the 90th percentile of the reference data set should be used. Most reference data sets available for water quality restoration planning and related TMDL development, particularly those dealing with sediment and habitat alterations, would tend to be “fair” to “good” quality. This is primarily due to a the limited number of available reference sites/data points available after applying all potentially applicable stratifications on the data, inherent variations in monitoring results among field crews, the potential for variations in field methodologies, and natural yearly variations in stream systems often not accounted for in the data set.

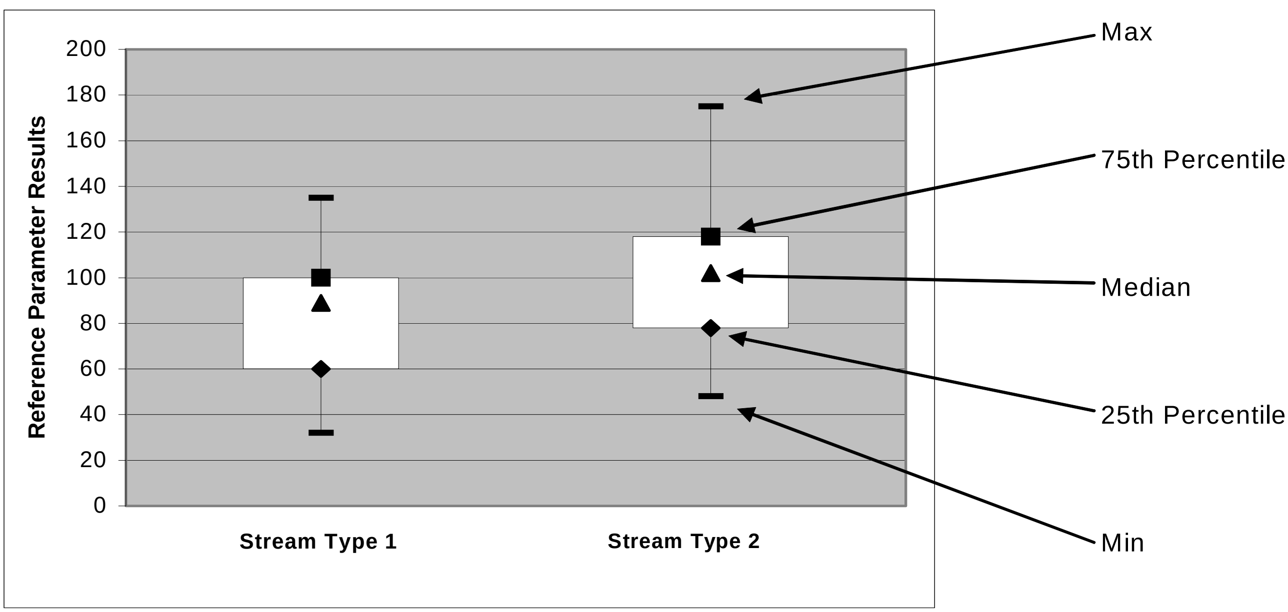


Figure B-1. Boxplot Example for Reference Data.

The above 25th – 75th percentile statistical approach has several considerations:

1. It is a simple approach that is easy to apply and understand.
2. About 25% of all streams would naturally fall into the impairment range. Thus, it should not be applied unless there is some linkage to human activities that could lead to the observed conditions. Where applied, it must be noted that the stream’s potential may prevent it from achieving the reference range as part of an adaptive management plan.

3. About 25% of all streams would naturally have a greater water quality potential than the minimum water quality bar represented by the 25th to 75th percentile range. This may represent a condition where the stream's potential has been significantly underestimated. Adaptive management can also account for these considerations.
4. Obtaining reference data that represents a naturally occurring condition, as defined above in **Table B-4**, can be difficult, particularly for larger waterbodies with multiple land uses within the drainage. This is because all reasonable land, soil, and water conservation practices may not be in place in many larger water bodies across the region. Even if these practices are in place, the proposed reference stream may not have fully recovered from past activities, such as riparian harvest, where reasonable land, soil, and water conservation practices were not applied.
5. A stream should not be considered impaired unless there is a relationship between the parameter of concern and the beneficial use such that not meeting the reference range is likely to cause harm or other negative impacts to the beneficial use as described by the WQS in **Table B-2**. In other words, if not meeting the reference range is not expected to negatively impact aquatic life, cold water fish, or other beneficial uses, then an impairment determination should not be made based on the particular parameter being evaluated. Relationships that show an impact to the beneficial use can be used to justify impairment based on the above statistical approach.

As identified in (2) and (3) above, there are two types of errors that can occur due to this or similar statistical approaches where a reference range or reference value is developed: (1) A stream could be considered impaired even though the naturally occurring condition for that stream parameter does not meet the desired reference range or (2) a stream could be considered not impaired for the parameter(s) of concern because the results for a given parameter fall just within the reference range, whereas the naturally occurring condition for that stream parameter represents much higher water quality and beneficial uses could still be negatively impacted. The implications of making either of these errors can be used to modify the above approach, although the approach used will need to be protective of water quality to be consistent with DEQ guidance and WQS (DEQ 2004). Either way, adaptive management is applied to this water quality plan and associated TMDL development to help address the above considerations.

Where the data do suggest a normal distribution or reference data is presented in a way that precludes use of non-normal statistics, the above approach can be modified to include the mean plus or minus one standard deviation to provide a similar reference range with all of the same considerations defined above.

Options When Regional Reference Data is Limited or Does Not Exist

In some cases, there is very limited reference data and applying a statistical approach like above is not possible. Under these conditions the limited information can be used to develop a reference value or range, with the need to note the greater level of uncertainty and perhaps a greater level of future monitoring as part of the adaptive management approach. These conditions can also lead to more reliance on secondary type approaches for reference development as defined in **Section B.1.3.1**.

Another approach would be to develop statistics for a given parameter from all streams within a watershed or region of interest (EPA 2000). The boxplot distribution of all the data for a given parameter can still be used to help determine potential target values knowing that most or all of the streams being evaluated are either impaired or otherwise have a reasonable probability of having significant water quality impacts. Under these conditions you would still use the median and the 25th or 75th percentiles as potential target values, but you would use the 25th and 75th percentiles in a way that is opposite from how you use the results from a regional reference distribution. This is because you are assuming that, for the parameter being evaluated, as many as 50% to 75% of the results from the whole data distribution represent questionable water quality. **Figure B-2** is an example statistical distribution where higher values represent better water quality. In **Figure B-2**, the median and 25th percentiles represent potential target values versus the median and 75th percentiles discussed above for regional reference distribution. Whether you use the median, the 25th percentile, or both should be based on an assessment of how impacted all the measured streams are in the watershed. Additional consideration of target achievability is important when using this approach. Also, there may be a need to also rely on secondary reference development methods to modify how you apply the target and/or to modify the final target value(s). Your certainty regarding indications of impairment or non-impairment may be lower using this approach, and you may need to rely more on adaptive management as part of TMDL implementation.

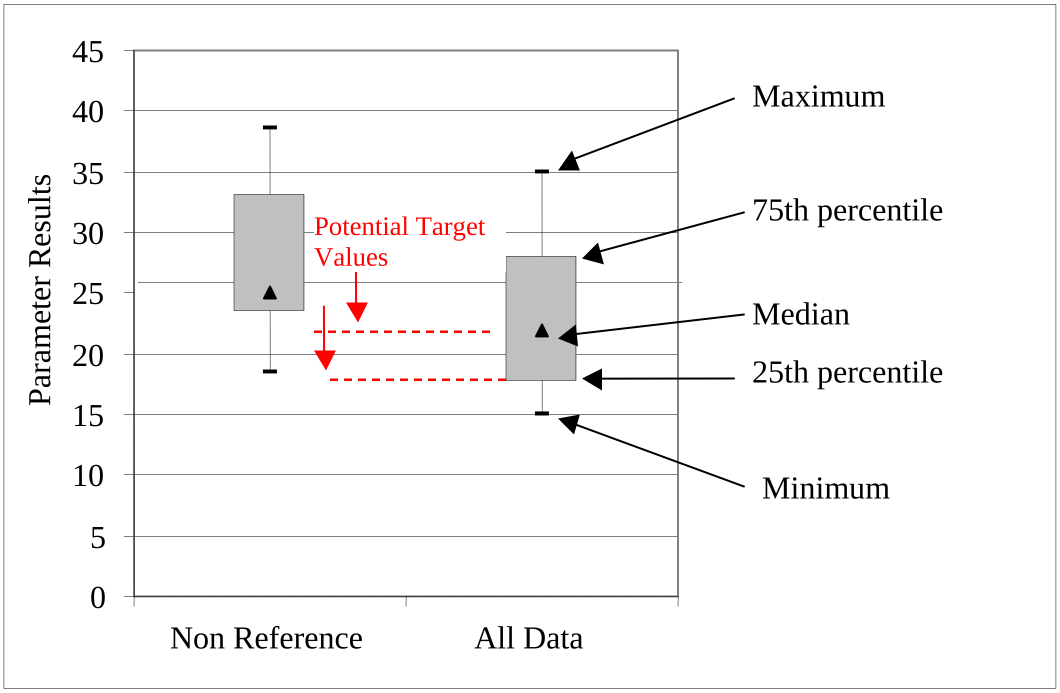


Figure B-2. Boxplot example for the use of all data to set targets.

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APPENDIX C
REFERENCE VALUE DEVELOPMENT & TARGET JUSTIFICATION

Reference condition values for various water quality parameters were identified using the guidance presented in **Section 3.0** and **Appendix B**. In general, reference conditions represent either conditions that have not been noticeably affected by anthropogenic activities (in other words, natural conditions) or conditions that represent the best water quality/land conditions achievable through the proper implementation of all best management practices if a return to natural condition is unachievable or unreasonable.

Potential internal reference reaches were identified via aerial assessments, but, during field reconnaissance, the reaches were determined to be more than minimally impacted by anthropogenic sources. Thus, no internal reference data were available for target development. Regional reference data provide the primary approach for most parameters and are used in conjunction with secondary reference approaches.

The suite of water quality targets and supplemental indicators selected for the Shields River TPA are listed below and described in detail within this appendix. The water quality targets are considered to be the most reliable and robust measures of the pollutant. Supplemental indicators are typically not sufficiently reliable to be used alone as a measure of support. These are used as supplemental information, in combination with the water quality targets, to better define potential problems caused by a pollutant.

<u>Water Quality Targets</u>:

- Percent Surface Fines in Riffles < 6.35 mm (pebble count)
- Percent Surface Fines in Riffles < 2 mm (pebble count)
- Percent Surface Fines < 6.35 mm in Pool Tails (grid toss or equivalent)
- Width-to-Depth Ratio (ratio of bankfull width to bankfull depth at riffle cross sections)
- Macroinvertebrate Population Metrics

<u>Supplemental Indicators</u>:

- Entrenchment Ratio
- Bank Erosion Hazard Index (BEHI) values
- Percent Eroding Banks
- Significant Human Caused Sources

The above parameters cover a broad range of direct habitat measures and measures of channel conditions, as well as a direct measure of aquatic life (macroinvertebrate metrics). All of the above parameters are measures of sediment-related stream health and can help define sediment-related impairments. Specific values for the targets and supplemental indicators are based on the best available data, but may be modified in the future as additional reference data within the watershed are collected or if they are determined to be inappropriate relative to the natural loading rate.

C.1 Channel Morphology and Substrate Measurements

USFS data for approximately 200 reference sites were used as a basis for determining departure from reference geomorphic condition and substrate size distribution. Approximately 70 of the reference sites were from the Greater Yellowstone Area, while the remaining sites were surveyed within the Beaverhead-Deerlodge National Forest (BDNF, n.d.). Streams described as "reference" were not necessarily in pristine watersheds, though the streams had to be stable and in "proper functioning condition." The entire reference dataset is available upon request from the BDNF and has been provided to the Montana DEQ.

The 75th percentile was calculated from the reference dataset and will be used as a basis for sediment water quality targets (**Table C-1**). Since the water quality target depends on the stream type, the term "comparable to reference values" should be interpreted as "less than or equal to" the 75th percentile for the percent surface fines, width/depth ratio, and BEHI, while "comparable to reference values" should be interpreted as "greater than or equal to" the 75th percentile for the entrenchment ratio. In essence, lower values for surface fine sediment, width/depth ratio, and BEHI rating are more desirable and suggest support of the cold water fishery and aquatic life beneficial uses. In general, higher values are desirable for the entrenchment ratio. No fine sediment targets (i.e. percent surface fines in riffles and pools) will be applied to the low gradient E streams in the Shields River TPA because these stream types naturally have high amounts of fine sediment, regional reference sediment values vary greatly, and there is insufficient internal reference data.

The 75th percentiles of entrenchment ratios for C and E channels in the reference dataset range from 3.7 to 15.9 (**Table C-1**). Although a higher entrenchment ratio is more desirable, if a channel is not entrenched, having an even higher ratio does not indicate a problem and is not a reasonable target. Rosgen and Silvey (1996) define a slightly entrenched C or E channel as having an entrenchment ratio greater than 2.2. Although this number is a generalization based on channel type data collected throughout the U.S. and not as applicable as regional reference data, it provides a frame of reference for an unentrenched channel. The smallest reference entrenchment ratio for a C channel is 5.1 and for an E channel is 3.7. These numbers will be used as the entrenchment ratio target for C and E channels.

Table C-1. Greater Yellowstone Area and Beaverhead Deerlodge National Forest Reference Dataset 75th Percentiles for Individual Rosgen Stream Types.

Parameter	B3	B4	B	C3	C4	C	E3	E4	E
% surface fines < 6mm	12	25	20	14	29	29	20	38	44
Width/Depth Ratio	15	17	16	31	20	23	10	7	7
Entrenchment Ratio	1.8	1.9	1.8	5.1	~~14.1~~	~~10.1~~	~~14.0~~	~~15.9~~	3.7
Reach Average BEHI	27.1	31.7	29.7	26.9	26.5	26.5	26.3	24.2	23.6

C.2 Percentage Surface Fine Sediment

The percent of surface fines less than 6 mm and 2 mm is a measurement of the fine sediment on the surface of a stream bed and is directly linked to the support of the cold water fishery and aquatic life beneficial uses. Increasing concentrations of surficial fine sediment can negatively affect salmonid growth and survival (Magee et al. 1996; Suttle et al. 2004) and

macroinvertebrate abundance and taxa richness (Mebane 2001; Zweig et al. 2001). Some studies of salmonid and macroinvertebrate survival found an inverse relationship between fine sediment and survival (Reiser and White 1988; Suttle et al. 2004) whereas other studies have concluded the most harmful percentage falls within 10 and 40 percent fine sediment (Bjornn et al. 1977; Bjornn and Reiser 1991; Relyea et al. 2000).

The <6 mm fine sediment target for riffles is based on Wolman pebble count reference data from within the Greater Yellowstone Area and the BDNF (**Table C-1**). Particularly for B and C channel types, the reference dataset correlates with a study by Mebane (2001), which was based on Wolman riffle pebble counts and found the greatest number of salmonid and sculpin age classes when the 75th percentile of fine sediment <6 mm was less than 20-30%. The USFS dataset is based on the "zigzag" pebble count method, which includes multiple habitat types (e.g. riffles and pools), and because the riffle pebble count is only from riffles, it is more likely to provide lower fines estimations than the zigzag method. Nonetheless, comparisons with 2004 Shields River pebble count datasets are reasonable and make a stronger case for sediment impairment if the 75th percentiles of the reference values are exceeded.

The Greater Yellowstone Area and BDNF reference dataset does not include substrate size classes smaller than 6 mm. Other regional data from pebble counts in the Middle Blackfoot Watershed, Nevada Creek Watershed, and Kootenai National Forest generally found fine sediment <2 mm to comprise less than 10% of riffle substrate. As the Shields River watershed is mostly in the Northwestern Great Plains ecoregion, which has a higher background level of fine sediment than most of the reference data, a target range of less than 10-15% fine sediment <2 mm will be used for riffles. Since sediment <2 mm is a fraction of the sediment <6 mm, this correlates well with most of the <6 mm regional data for sediment being greater than 15% (**Table C-1**). For all sites sampled on the Shields River (n=9), the median value was 3 % fines <2 mm and the 75th percentile was 7%. Based on reference values, literature values, and field observations, a target of less than 10-15% sediment <2 mm is protective of beneficial uses and feasible.

C.3 Percent Surface Fines in Pool Tail-Out Gravels

A 49-point grid toss was used to estimate percent surface fines in pool tails; four grid tosses were performed in each pool tail, and the total percentage of fine sediment for each pool was averaged with all other pools in each sample reach. The wire grid method is less-commonly used for determining percent fines in surface substrate than the Wolman pebble count, but provides the advantage of focusing on critical habitat, and is therefore more directly related to aquatic habitat support.

A particle size of 6 mm is commonly used to define fine sediment because of its potential to clog spawning redds and smother fish eggs by limiting oxygen availability (Irving and Bjornn 1984; Shepard et al. 1984). Survival of several salmonid species greatly declines as subsurface fine sediment <6 mm increases (Shepard et al. 1984; Reiser and White 1988; Weaver and Fraley 1991). Increasing surface fine sediment <6 mm also negatively affects both salmonids and sculpins (Mebane 2001), and sedimentation of pools reduces summer and overwintering habitat, causing a reduction in pool salmonid density (Bjornn et al. 1977).

Reference development for percent surface fines using the grid-toss method is based on results from several studies (**Table C-2**). Some of the reference data are from least impacted streams, and because of limited least impacted streams in other watersheds, other reference data are from percentiles from entire sample datasets. Because excess sediment was noted in most pool tails during field work in the Shields River TPA and there were no internal reference sites, it is not reasonable to use a percentile of the dataset. Instead, the target is based on reference data from regional watersheds. Because the Shields River TPA is mostly in the Northwestern Great Plains ecoregion, which has a higher background level of fine sediment than much of the reference data, the pool tail target is on the higher end of the regional reference data. The most applicable regional reference data are from the Middle Blackfoot and Nevada Creek watersheds. Based on conditions within the Shields River TPA and available reference data, the water quality target for percent surface fine sediment <6 mm in pool tails is a reach average less than 20% for B and C channels.

Table C-2. Regional reference data for grid toss surface fines (<6 mm)

Source	Percent Fines
Blackfoot Headwaters TMDL Reference Condition	6 – 8 (75th percentile)
Lolo NF (USFS 1998)	6 – 8 (Average); 10 – 15 probable range of 75th percentiles
Prospect Creek Watershed	13 (Average); 6 (median); 14 (75th percentile)
Ruby River Watershed	B channel: 8 (median)
	C channel: 6 (median)
	Ea channel: 7 (median)
Middle Blackfoot Watershed	B channel: 17 (75th percentile from Nevada Creek data)
	C channel: 20 (75th percentile)
	E channel: 48 (75th percentile of reference)
Nevada Creek Watershed	B channel: 17 (75th percentile)
	C channel: 23 (75th percentile of reference)
	E channel: 82 (25th percentile)

C.4 Width/Depth Ratio and Entrenchment Ratio

The width/depth ratio and the entrenchment ratio are fundamental aspects of channel morphology, and each provides a measure of channel stability, as well as an indication of the ability of a stream to transport and naturally sort sediment into a heterogeneous composition of fish habitat features (i.e. riffles, pools, and near bank zones). Width/depth ratio is the ratio of channel bankfull width to the mean bankfull depth, and the entrenchment ratio is the ratio of the width of the flood-prone area to the channel bankfull width (Rosgen and Silvey 1996). In essence, the entrenchment ratio is the vertical containment of a stream, or how easily it can access its floodplain. Changes in both the width/depth ratio and entrenchment ratio can be used as indicators of change in the relative balance between the sediment load and the transport capacity of the stream channel. As the width/depth ratio increases, streams become wider and shallower, suggesting an excess coarse sediment load (MacDonald et al. 1991). As sediment accumulates, the depth of the stream channel decreases, which is compensated for by an increase in channel width as the stream attempts to regain a balance between sediment load and transport capacity. Conversely, a decrease in the entrenchment ratio signifies a loss of access to the floodplain. Low entrenchment ratios signify that stream energy is concentrated in-channel during flood events versus having energy dissipation on the floodplain. Accelerated bank erosion and an

increased sediment supply often accompany an increase in the width/depth ratio and/or a decrease in the entrenchment ratio (Knighton 1998, Rowe et al. 2003, Rosgen and Silvey 1996).

During data collection in 2004 (as discussed in **Section 4.5**), width/depth and entrenchment ratios were measured at five cross sections per reach. The reach median width/depth ratios and entrenchment ratios collected in 2004 will be compared to the reference range for the appropriate stream type (see **Table C-1**). Width/depth ratio will be used as a water quality target for sediment impairments, and, because entrenchment is not as responsive to land-use changes within the watershed as the width/depth ratio, entrenchment will be used as a supplemental indicator.

C.5 Macroinvertebrates

Siltation exerts a direct influence on benthic macroinvertebrates assemblages through several mechanisms. These include limiting preferred habitat for some taxa by filling in interstices or spaces between gravel. In other cases, fine sediment limits attachment sites for taxa that affix to substrate particles. Macroinvertebrate assemblages respond predictably to siltation with a shift in natural or expected taxa to a prevalence of sediment tolerant taxa over those that require clean gravel substrates. Macroinvertebrate bioassessments scores are an assessment of the macroinvertebrate assemblage at a site, and are used by the Montana DEQ to evaluate impairment condition and beneficial use support. The advantage to these bioindicators is that they provide a measure of support of associated aquatic life, an established beneficial use of Montana's waters. Although macroinvertebrates provide an important measure of aquatic life support, they are used as a supplemental indicator for support of sediment impairment because they can be affected by other impairments (e.g. nutrients and metals).

In 2006, Montana DEQ adopted impairment thresholds for bioassessment scores based on two separate methodologies. The **Multi-Metric Index (MMI)** method assesses biologic integrity of a sample based on a battery of individual biometrics. The **River Invertebrate Prediction and Classification System (RIVPACS)** method utilizes a probabilistic model based on the taxa assemblage that would be expected at a similar reference site. Based on these tools, DEQ adopted bioassessment thresholds that were reflective of conditions that supported a diverse and biologically unimpaired macroinvertebrate assemblage, and therefore a direct indication of beneficial use support for aquatic life. The rationale and methodology for both indices are presented in, "Biological Indicators of Stream Condition in Montana Using Benthic Macroinvertebrates," (Jessup et al., 2006).

The MMI is organized based on three different bioregions within Montana. The three MMIs are Mountain, Low Valley, and Plains. Each region has specific bioassessment threshold criteria that represent full support of macroinvertebrate aquatic life uses. The Shields River watershed falls within both Mountain and Plains MMI bioregions. The Plains MMI is most applicable to the typical warmwater eastern Montana plains stream. Because the Shields River is at the border of the Northern Great Plains ecoregion and predominantly a coldwater fishery, the Low Valley MMI is a more appropriate tool and will be used instead of the Plains MMI to evaluate macroinvertebrates in the mainstem Shields River. The Plains MMI is appropriate for Potter Creek and Antelope Creek and will be used to assess macroinvertebrate populations in those

water bodies. The MMI score is based upon the average of a variety of individual metric scores. The metric scores measure predictable attributes of benthic macroinvertebrate communities to make inferences regarding aquatic life condition when pollution or pollutants affect stream systems and in-stream biota. For the MMI, individual metric scores are averaged to obtain the final MMI score, which ranges between 0 and 100. **The impairment thresholds are 63 for the Mountain MMI, 48 for the Low Valley MMI, and 38 for the Plains MMI.** These values are established as water quality targets for sediment impairments in the Shields River TPA. The impairment threshold (10^{th} percentile of the reference dataset) represents the point where DEQ technical staff believes macroinvertebrate populations are affected by some kind of impairment (e.g. loss of sensitive taxa), and an MMI score less than the threshold suggests impairment.

The RIVPACS model compares the taxa that are expected at a site under a variety of environmental conditions with the actual taxa that were found when the site was sampled. The RIVPACS model provides a single dimensionless ratio to infer the health of the macroinvertebrate community. This ratio is referred to as the Observed/Expected (O/E) value. Used in combination, the results suggest strong evidence that a water body is either supporting or non-supporting its aquatic life uses for aquatic invertebrates. **The RIVPACS impairment threshold for all Montana streams is any O/E value <0.8.** However, the RIVPACS model has a bidirectional response to nutrient impairment. Some stressors cause macroinvertebrate populations to decrease right away (e.g. metals contamination) which causes the score to decrease below the impairment threshold of 0.8. Nutrient enrichment may actually increase the macroinvertebrate population diversity before eventually decreasing below 0.8. The 90^{th} percentile of the reference dataset was selected (1.2) to account for these situations and any value above this score may present support for nutrient impairment (Feldman 2006). However, RIVPACS scores >1.0 are considered unimpaired for all other stressor types. A supplemental indicator value RIVPACS score of >0.80 is established for sediment impairments in the Shields River TPA. A score of greater than 1.2, when combined with other data, may present support for nutrient impairment (Feldman 2006).

C.6 Bank Erosion Hazard Index (BEHI)

Stream flows, sediment loads, riparian vegetation, and streambank material all influence bank stability, which, in turn, influences sediment contribution to the stream. The BEHI is a composite metric of streambank characteristics that affect overall bank integrity and is determined based on bank height, bankfull height, rooting depth, bank angle, surface protection, and bank materials/composition (Rosgen and Silvey 1996). Measurements for each metric are combined to produce an overall score or “rating” of bank erosion potential. Low BEHI values indicate a low potential for bank erosion. A bank erosion hazard index beyond the reference range for the appropriate stream type (see **Table C-1**) will be used as a supplemental indicator for sediment impairments.

The percent of eroding streambanks within a survey reach will be applied as a supplemental indicator for sediment impairments. Since streambank erosion is a natural process, this indicator will be used with caution. For example, just because eroding banks are present does not necessarily mean the erosion is human-induced or that there is an in-stream sediment problem. Additional information, such as observed bank trampling, removal of stabilizing vegetation, or

increased water yield from timber harvest, will be considered. Departure from reference condition will apply when the percent of eroding banks within a survey reach exceeds 15% for B, C, and E type streams. These values are based on least impacted stream surveys in the Ruby Watershed.

C.7 Significant Human Caused Sediment Sources

Human caused sources need to be present for a TMDL to be written. If the only departure from reference conditions are stream channel conditions that do not affect sediment transport, a habitat restoration plan will be written. TMDLs need to address a reduction of sediment from applying restoration practices to human caused activities. The analysis that supports this parameter is supplied in the Sediment Source Assessment Section (**Section 7.0**) of this document.

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APPENDIX D
SEDIMENT CONTRIBUTION FROM ROADS

Approach

Sediment delivery from roadways was estimated using WARSEM, a Microsoft Access based model developed for and used by the State of Washington Department of Natural Resources for assessing sediment production and delivery to streams from roads under its jurisdiction. WARSEM is an empirical model and estimates sediment production and delivery based on road surfacing, road use, underlying geology, precipitation, road age, road gradient, road prism geometry (including road configuration and ditch geometry), cut slope cover, and other factors (Dube' et al 2004).

Data Sources

For a Level 3 assessment, defined in the WARSEM documentation as "detailed assessment and scenario playing," the following parameters are required and must be field verified: Road location, surfacing, geology, segment length, road width, road gradient, delivery type, road configuration and prism geometry, cut slope height, cut slope cover, and ditch width. Traffic level is a parameter that is required, but may be estimated and need not be field verified. Three parameters are optional: Ditch condition, BMPs, and road age.

Data were collected and field verified for all but two of the required parameters: Road age and geology. Road age was estimated as per the model requirements. Budget constraints did not permit sending a geologist to the field to verify these data for each sampled road segment, but, given the coarse graduation of the effect of the geology parameter on model results (high, med, and low erosion classes), the greater accuracy of our method of assigning geology data to a sample location versus that assumed by the model (GIS overlay of specific lat/long positions, as opposed to general location by public land survey section number) we do not believe that this adversely affects the validity of the results.

WARSEM uses internal datasets for its rainfall and (non-field-verified) geology parameters. The user does not enter these data directly; they are derived based on the location of the sample site. These internal datasets are only defined for Washington State. We modified the WARSEM model, adding Montana specific datasets for these parameters. The geology erosion factor parameter was derived from data obtained from GIS coverage of the USGS 1:500K geology map of Montana. Appropriate values were determined based on a table of values for a variety of geologies (Dube' et al. 2004). The rainfall factor parameter was derived form PRISM precipitation data obtained from the Spatial Climate Analysis Service at Oregon State University. The PRISM data set gives mean monthly and annual precipitation levels for the United States at a resolution of 4 kilometers.

To extrapolate the WARSEM model results from the sampled road segments to the watershed as a whole, comprehensive datasets representing the locations of roads and streams were needed. We used GIS coverage of 2000 TIGER road data for road locations and the national hydrography dataset (NHD) for stream locations. We supplemented the sparse coverage of local roads in the TIGER data by digitizing additional road locations from 1:24,000 scale digital orthophotos.

Methods

Field data collection

The WARSEM assumes that roads greater than 200 feet from a stream do not deliver sediment to that stream unless a roadside ditch or gully is present to convey flow from the road to the stream or a point within 200 feet of the stream. Buffering the stream layer by 200 feet and intersecting this buffer with the roads data using GIS methods, identified potential sample locations for collecting field data as well as road segments to which the model results would be extrapolated. The field-sampling plan for the road data allocated the samples to be taken according to attributes which could be readily identified from GIS databases and which corresponded to the WARSEM parameters with the greatest effect on model results. Potential sample locations were stratified according to:

- Road type from the TIGER data. This was assumed to be an indicator of road surface, tread width, and traffic use.
- Ownership (USFS vs. other). This was assumed an indication of road surface, slope, traffic use, and management practices.
- STATSGO soil unit. This was assumed to be indicative of cut slope and ditch condition. It offers a finer division than the gross geology of the parent material on which the road was constructed.

As the variability of these attributes over the sample locations could not be predicted, sample locations were first chosen proportionally in accordance to the frequency of each combination of the values of those attributes, and the proportions were then adjusted to ensure that the more rare combinations of these attributes would have a sufficient number of samples taken to be statistically representative. As implemented, budget considerations resulted in fewer than the recommended number of samples being taken, and those were targeted toward the permutations that represented the greatest proportion of the roads in the watershed

Field crews were trained in collecting road data according to the assumptions and specifications of the WARSEM model and provided the appropriate equipment (clinometer, measuring tape, GPS, etc) to make accurate measurements. Locations of road sampling locations are shown in **Figure D-1.**

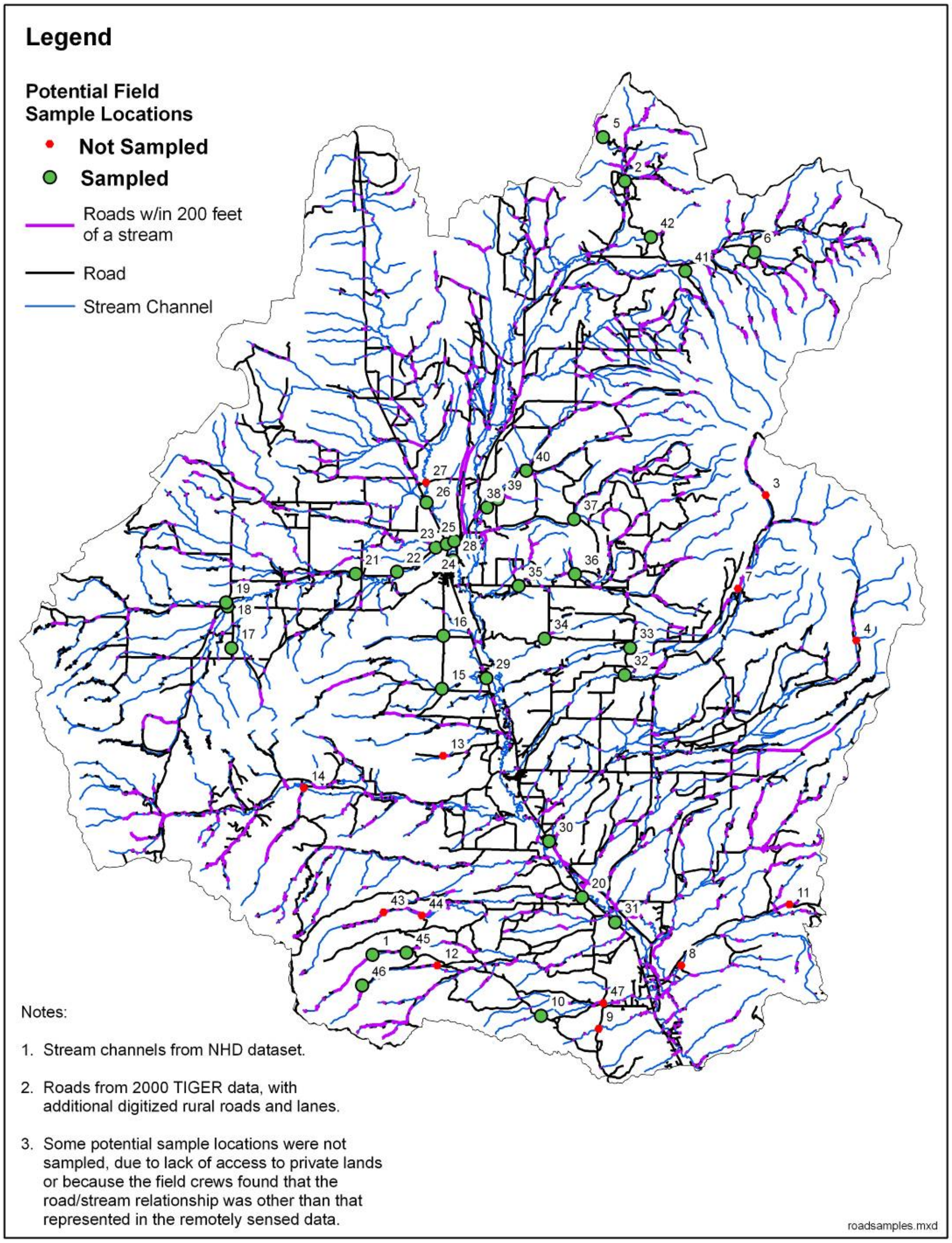

Figure D-1. Road sediment field sampling locations

When field crews noted existing BMPs at the sampled sites, the effect of the BMPs was included in the modeling of sample sites in the WARSEM by applying the appropriate model inputs to describe the observed BMPs. For example, rubber water diverters may have shortened the contributing segment length. If road surface BMPs were encountered model inputs reflected the existing field conditions. As a result, the existing BMPs were taken into account and were extrapolated throughout the watershed.

Model run and extrapolation

The WARSEM was run using the collected and derived input data, resulting in a predicted sediment delivery in tons/yr for each field sample segment. Extrapolation to the entire watershed was based on 2 parameters - Road Class and Road/Stream Orientation. Each road segment (within 200 feet of an NHD stream) in the GIS was assigned values for each of these categories. The Road Class category consisted of the following road types: 4x4, Local, Highway, Ranch, and Unknown. The Road/Stream Orientation category consisted of the following segment types: Crossing (for road segments that cross streams) and parallel (for road segments that are adjacent to streams but do not cross them). Ten extrapolation classes resulted from the combination of these parameters: 4x4Xing, LocalXing, HwyXing, RanchXing, UnknownXing, 4x4Para, LocalPara, HwyPara, RanchPara, and UnknownPara. The surveyed sites were broken down by extrapolation class and WARSEM was used to predict sediment delivery from each of the surveyed sites. An extrapolation factor was developed for each extrapolation class based on WARSEM results and the GIS.

$$ExtrapFactor = \frac{\sum_{i=1}^{n}\left[\frac{TS_i}{LGIS_i}\right]}{n} \qquad (1)$$

Where: *TS = total sediment delivery predicted by WARSEM for a given sample site (tons/year)*
LGIS = length of road within 200 ft of a stream at a given sample site as predicted by the GIS (ft)
n = number of sample sites for the extrapolation class in question

Adequate sample site data was not available to develop extrapolation factors for the following extrapolation classes: RanchXing, UnknownXing, RanchPara, and UnknownPara. To overcome this data deficit, certain assumptions were made to develop a complete set of extrapolation parameters.

No data were collected from Ranch road segments. It was assumed that Ranch roads include both 4x4 and Local roads on private land. The ratio of 4x4 segments to Local segments within 200 feet of a stream was 14.4% : 85.6%. This ratio was used to create a road class weighted average extrapolation factor for Ranch roads by the following equations:

RanchXing = 0.856 (LocalXing) + 0.144 (4x4Xing)

RanchPara = 0.856 (LocalPara) + 0.144 (4x4Para)

Road segments not shown on the TIGER dataset and subsequently digitized to enhance the coverage of the data did not have a specific road class assigned to them. It was assumed that the Unknown road segments included both 4x4 and Local roads. The ratio of 4x4 segments to Local segments within 200 feet of a stream was 14.4% : 85.6%. This ratio was used to create a road class weighted average extrapolation factor for Unknown roads by the following equations:

UnknownXing = 0.856 (LocalXing) + 0.144 (4x4Xing)

UnknownPara = 0.856 (LocalPara) + 0.144 (4x4Para)

The resulting units of the extrapolation factor are Tons of sediment per year per foot of GIS measured length. Prediction of the sediment delivered from all roads in the GIS was accomplished by multiplying the length of a given road segment in the GIS by the extrapolation factor for the matching extrapolation class.

BMP Application Scenarios

The TMDL process requires the comparison of existing loads to natural background levels and to levels where reasonable land, soil, and water conservation practices are in place. The WARSEM allows users to evaluate the potential effects of many different road BMPs. The following BMP scenarios were modeled: *Installing Settling Basins at All Crossings, Installing Silt Fences at All Crossings, Applying Road Surface BMPs to Contributing Segments, and Applying Length Reducing BMPs at Crossings.*

Settling Basins at All Crossings – This is a prediction of sediment loads if effective settling basins were installed at all road/stream *crossings*. Based on literature values, WARSEM assumes that using properly sized and designed settling basins that do not overtop during large storms can result in trap efficiencies of 85%. Therefore, predicted deliveries (existing conditions) were reduced by 85%.

Silt Fences at All Crossings - This is a prediction of sediment loads if silt fences or hay bales were installed at all road/stream *crossings*. Based on existing research, WARSEM assumes that using these BMPs can result in trap efficiencies of 25%. Therefore, predicted deliveries (existing conditions) were reduced by 25%.

Road Surface BMPs – All reductions from altering road surface conditions were based on the following matrix (**Table D-1**) that was developed from WARSEM road surface parameters. The numbers in the matrix are multipliers used to determine the resulting sediment delivery if the road surface is changed from the condition listed at left side of the table to the condition listed at the top of the table.

Table D-1. Road Surface Sediment Reduction Multiplier Matrix

			TO						
			native/ruts	native	grassed	pit run	gravel/ruts	gravel	asphalt
			2	1	0.5	0.5	0.4	0.2	0.03
FROM	native/ruts	2	1	0.5	0.25	0.25	0.2	0.1	0.015
	native	1	x	1	0.5	0.5	0.4	0.2	0.03
	grassed	0.5	x	x	1	1	0.8	0.4	0.06
	pit run	0.5	x	x	x	1	0.8	0.4	0.06
	gravel/ruts	0.4	x	x	x	x	1	0.5	0.075
	gravel	0.2	x	x	x	x	x	1	0.15
	asphalt	0.03	x	x	x	x	x	x	1

From the WARSEM manual,

> "Unsurfaced (native) roads are often referred to as dirt roads. They have not had any gravel or other surface applied to them. In a few cases, the underlying rock is so hard the road appears to have a gravel surface, and should be coded as such, but these instances are rare."
>
> "Gravel surfacing refers to a good layer of gravel, with few fines, dust, or dirt on the surface. You should be able to see mostly gravel-sized particles on these road surfaces."
>
> "Pitrun surfaces refer to poor quality or very worn gravel surfaces with lots of fines or dust. Gravel particles are visible, but most of the surface is worn down into fine particles."

Asphalt surfacing refers to roads that are paved with tarmac or blacktop (aka. Asphalt), and grassed surfacing refers to native ground or pitrun roads that are covered with grasses (either planted or naturally occurring).

Several BMP scenarios were based on changing road surfacing. Each is described in detail below.

Upgrade All Contributing Road Surfaces to Gravel – This is a prediction of sediment loads if the surfaces of all contributing road segments are changed to gravel. Roads segments that currently have Gravel or asphalt surfaces remain unchanged.

Upgrade All Contributing Road Surfaces One Level – This is a prediction of sediment loads if the surfaces of all contributing road segments are upgraded one level. For example, gravel upgraded to asphalt, or native upgraded to pit run. Note that no surfaces were upgraded to a grassed surface as that practice is likely not feasible in many parts of the Shields.

Upgrade All Contributing Road Surfaces One Level (No Paving) – This is a prediction of sediment loads if the surfaces of all contributing road segments are upgraded one level, but none are changed to pavement. For example, pit run upgraded to gravel, or native upgraded to pit run. Note that gravel surfaced roads will not be upgraded to asphalt. Note that no surfaces were upgraded to a grassed surface as that practice is likely not feasible in many parts of the Shields.

Repair All Rutted Contributing Road Surfaces to Original Condition – This is a prediction of sediment loads if the surfaces of all contributing road segments classified as rutted are upgraded to their initial condition. For example, rutted native surfaces are upgraded to native surfaces.

Apply Length Reducing BMPs at Crossings - This is a prediction of sediment loads if length reducing BMPs are applied to all crossing segments. Because BMPs must be

selected on a site-by-site basis, no specific length reducing BMP was applied. Rather, the assumption was that one or more length reducing BMPs would be applied in a manner such that the length of the contributing segment would be reduced to 500 ft per crossing (USFS roads) or 100 ft per crossing (for all other roads). It is important to note that in reality, BMPs may not be applicable at some sites due to specific constraints and the actual result of applying BMPs will vary from site to site. The lengths of 500 ft and 100 ft were intended to represent reasonable average contributing lengths resulting from BMP installation at crossings and are not formal goals. Forest Service roads were treated differently from those owned by other agencies or private individuals to reflect the effect that varying topography, road management policy, and economic feasibility between owner categories.

Hybrid Scenario: Typically, all reasonable land, soil, and water conservation practices is a combination of road BMPs. Applying length reducing BMPs is one of the most widely used and most effective methods of reducing sediment loads but is not practical in all instances. In this regard, reductions for an additional scenario were calculated outside of the WARSEM. This scenario is a hybrid of two modeled scenarios: A reduction in the road contributing length at 60% of roads and an upgrade of contributing road surfaces by one level (with no paving) at 40% of roads. This hybrid of two modeled scenarios was selected as an example to illustrate the potential for sediment reduction by approximating BMP upgrades and is not a formal goal for all crossings. Achieving this reduction in sediment loading from roads may be occur through a wider variety of methods such as diverting water from road surfaces, ditch BMPs, and cut/fill slope BMPs.

Results

Hybrid Scenario: Typically, all reasonable land, soil, and water conservation practices is a combination of road BMPs. Applying length reducing BMPs is one of the most widely used and most effective methods of reducing sediment loads but is not practical in all instances. In this regard, reductions for an additional scenario were calculated outside of the WARSEM. This scenario is a hybrid of two modeled scenarios: a reduction in the road contributing length at 60% of roads and an upgrade of contributing road surfaces by one level (with no paving) at 40% of roads. T his hybrid of two modeled scenarios was selected as an example to illustrate the potential for sediment reduction by approximating BMP upgrades and is not a formal goal for all crossings. Achieving this reduction in sediment loading from roads may be occur through a wider variety of methods such as diverting water from road surfaces, ditch BMPs and cut/fill slope BMPs.

Hybrid Scenario: Typically, all reasonable land, soil, and water conservation practices is a combination of road BMPs. Applying length reducing BMPs is one of the most widely used and most effective methods of reducing sediment loads but is not practical in all instances. In this regard, reductions for an additional scenario were calculated outside of the WARSEM. This scenario is a hybrid of two modeled scenarios: A reduction in the road contributing length at 60% of roads and an upgrade of contributing road surfaces by one level (with no paving) at 40% of roads. This hybrid of two modeled scenarios was selected as an example to illustrate the potential for sediment reduction by approximating BMP upgrades and is not a formal goal for all crossings. Achieving this reduction in sediment loading from roads may be occur through a

wider variety of methods such as diverting water from road surfaces, ditch BMPs, and cut/fill slope BMPs.

Table D-2 contains the existing load from unpaved roads by subwatershed and the existing load normalized by the length of contributing roads in each subwatershed. **Table D-3** contains the results of the existing conditions and BMP scenario modeling based by 6th code HUC subwatersheds. The existing conditions and reductions for each BMP scenario are also presented by ownership and road class for 6th code HUC subwatersheds (**Tables D-4 and D-5**, respectively), and for the entire Shields River watershed by ownership, road class, and road orientation (**Table D-6**).

Table D-2. Existing and normalized existing loads from unpaved roads by subwatershed.

	Total contributing length within 200 ft of a stream	Existing Conditions	Normalized Existing Conditions
Subwatershed Name	**(Miles)**	**(Tons/yr)**	**(tons/mi/yr)**
Adair Creek	8.6	11	1.30
Bangtail Creek	6.5	4	0.65
Canyon Creek	7.8	8	0.98
Carrol Creek	3.8	4	1.05
Cottonwood Creek East	7.1	5	0.76
Cottonwood Creek West	6.8	8	1.12
Daisy Dean Creek	6.2	7	1.13
Dry Creek	4.5	6	1.36
Elk Creek	7.6	12	1.57
Falls Creek	14.8	14	0.97
Horse Creek	12.3	17	1.34
Lower Brackett Creek	6.4	6	0.86
Lower Flathead Creek	6.7	7	1.04
Lower Shields River-Chicken Creek	19.7	24	1.20
Lower Shields River-Crazyhead Creek	11.1	11	0.97
Meadows Creek	11.8	7	0.61
Middle Shields River-Antelope Creek	8.4	9	1.10
Middle Shields River-Spring Creek	3.2	4	1.31
Muddy Creek	8.1	7	0.90
Porquepine Creek	10.5	11	1.02
Potter Creek	11.5	11	0.97
Rock Creek	6.6	9	1.43
Upper Brackett Creek	18.0	23	1.25
Upper Flathead Creek	2.6	3	1.05
Upper Shields River-Antelope Creek	12.8	12	0.96
Upper Shields River-Bennett Creek	18.4	19	1.06
Upper Shields River-Kavanaugh Creek	7.9	8	1.02
Willow Creek	17.7	13	0.73
Grand Total (Shields Watershed)	**267.4**	**280**	**1.05**

Table D-3. Sediment Contribution and Potential Reductions from Unpaved Roads by Subwatershed

Subwatershed Name	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
	(Miles)	(Tons/yr)	(Tons/yr)	(Tons/yr)	(Tons/yr)	(Tons/yr)	(Tons/yr)	(Tons/yr)	(Tons/yr)	(Tons/yr)
Adair Creek	8.6	11	2	8	7	5	8	8	2	5
Bangtail Creek	6.5	4	1	3	3	2	3	3	1	2
Canyon Creek	7.8	8	1	6	6	4	5	6	2	3
Carrol Creek	3.8	4	1	3	2	2	3	3	1	2
Cottonwood Creek East	7.1	5	1	4	4	3	4	4	1	2
Cottonwood Creek West	6.8	8	1	6	5	4	5	6	1	3
Daisy Dean Creek	6.2	7	1	5	4	3	5	5	1	3
Dry Creek	4.5	6	1	5	3	3	4	5	1	2
Elk Creek	7.6	12	2	9	7	6	8	9	2	5
Falls Creek	14.8	14	2	11	13	7	10	11	3	6
Horse Creek	12.3	17	3	12	10	8	12	12	3	7
Lower Brackett Creek	6.4	6	1	4	4	3	4	4	1	2
Lower Flathead Creek	6.7	7	1	5	4	3	5	5	1	3
Lower Shields River-Chicken Creek	19.7	24	4	18	15	11	17	18	4	10
Lower Shields River-Crazyhead Creek	11.1	11	2	8	8	5	8	8	2	4
Meadows Creek	11.8	7	1	5	7	3	5	5	2	3
Middle Shields River-Antelope Creek	8.4	9	1	7	5	4	7	7	2	4
Middle Shields River-Spring Creek	3.2	4	1	3	3	2	3	3	1	2
Muddy Creek	8.1	7	1	6	5	3	5	6	1	3
Porquepine Creek	10.5	11	2	8	6	5	8	8	2	4
Potter Creek	11.5	11	2	8	7	5	8	8	2	5
Rock Creek	6.6	9	1	7	5	4	7	7	2	4

Table D-3. Sediment Contribution and Potential Reductions from Unpaved Roads by Subwatershed

Subwatershed Name	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
Upper Brackett Creek	18	23	4	17	13	11	16	17	5	9
Upper Flathead Creek	2.6	3	0	2	2	1	2	2	1	1
Upper Shields River-Antelope Creek	12.8	12	2	9	7	6	9	9	2	5
Upper Shields River-Bennett Creek	18.4	19	3	15	15	9	14	15	6	8
Upper Shields River-Kavanaugh Creek	7.9	8	1	6	4	4	6	6	2	3
Willow Creek	17.7	13	2	10	10	6	9	10	3	5
Shields River Watershed	267.4	280	46	211	185	131	199	210	56	113
Percent Reduction (from existing load)			84%	25%	34%	53%	29%	25%	80%	60%

Table D-4. Sediment contribution and potential reductions from unpaved roads by subwatershed and road ownership.

Subwatershed	Ownership	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
Adair Creek	Private/State	8.6	11	2	8	7	5	8	8	2	5
	USFS	0.0									
Bangtail Creek	Private/State	6.1	4	1	3	3	2	3	3	1	2
	USFS	0.4	<1	<1	<1	<1	0	<1	<1	<1	<1
Canyon Creek	Private/State	6.6	7	1	5	6	3	5	5	1	3
	USFS	1.2	1	<1	1	1	<1	1	1	<1	<1
Carrol Creek	Private/State	3.8	4	1	3	2	2	3	3	1	2
	USFS	0.0									
Cottonwood Creek East	Private/State	4.0	5	1	3	3	2	3	3	1	2
	USFS	3.1	1	<1	1	1	<1	1	1	<1	<1
Cottonwood Creek West	Private/State	6.8	8	1	6	5	4	5	6	1	3
	USFS	0.0									
Daisy Dean Creek	Private/State	6.2	7	1	5	4	3	5	5	1	3
	USFS	0.0									

Table D-4. Sediment contribution and potential reductions from unpaved roads by subwatershed and road ownership.

Subwatershed	Ownership	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
Dry Creek	Private/State	4.5	6	1	5	3	3	4	5	1	2
	USFS	0.0									
Elk Creek	Private/State	7.6	12	2	9	7	6	8	9	2	5
	USFS	0.0									
Falls Creek	Private/State	14.8	14	2	11	13	7	10	11	3	6
	USFS	0.0									
Horse Creek	Private/State	12.3	17	3	12	10	8	12	12	3	7
	USFS	0.0									
Lower Brackett Creek	Private/State	6.4	6	1	4	4	3	4	4	1	2
	USFS	0.0									
Lower Flathead Creek	Private/State	6.7	7	1	5	4	3	5	5	1	3
	USFS	0.0									
Lower Shields River-Chicken Creek	Private/State	19.7	24	4	18	15	11	17	18	4	10
	USFS	0.0									

Table D-4. Sediment contribution and potential reductions from unpaved roads by subwatershed and road ownership.

Subwatershed	Ownership	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
Lower Shields River-Crazyhead Creek	Private/State	11.1	11	2	8	8	5	8	8	2	4
	USFS	0.0									
Meadows Creek	Private/State	3.8	2	<1	2	2	1	1	1	<1	1
	USFS	8.0	5	1	4	5	2	4	4	2	2
Middle Shields River-Antelope Creek	Private/State	8.4	9	1	7	5	4	7	7	2	4
	USFS	0.0									
Middle Shields River-Spring Creek	Private/State	3.2	4	1	3	3	2	3	3	1	2
	USFS	0.0									
Muddy Creek	Private/State	8.1	7	1	6	5	3	5	6	1	3
	USFS	0.0									
Porquepine Creek	Private/State	10.5	11	2	8	6	5	8	8	2	4
	USFS	0.0									
Potter Creek	Private/State	11.5	11	2	8	7	5	8	8	2	5

Table D-4. Sediment contribution and potential reductions from unpaved roads by subwatershed and road ownership.

Subwatershed	Ownership	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
	USFS	0.0									
Rock Creek	Private/State	5.7	9	1	7	5	4	6	7	2	4
	USFS	0.0									
Upper Brackett Creek	Private/State	15.1	19	3	15	11	9	14	15	3	8
	USFS	2.9	3	<1	2	2	2	2	2	1	1
Upper Flathead Creek	Private/State	2.6	3	<1	2	2	1	2	2	1	1
	USFS	0.0									
Upper Shields River-Antelope Creek	Private/State	12.8	12	2	9	7	6	9	9	2	5
	USFS	0.0									
Upper Shields River-Bennett Creek	Private/State	5.0	6	1	5	4	3	4	5	1	3
	USFS	13.3	13	2	10	11	6	9	10	5	5
Upper Shields River-Kavanaugh Creek	Private/State	7.9	8	1	6	4	4	6	6	2	3
	USFS	0.0									

Table D-4. Sediment contribution and potential reductions from unpaved roads by subwatershed and road ownership.

Subwatershed	Ownership	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
Willow Creek	Private/State	13.5	12	2	9	8	5	8	9	2	5
	USFS	4.2	1	<1	1	2	1	1	1	1	1

Table D-5. Sediment contribution and potential reductions from unpaved roads by subwatershed and road class.

Subwatershed	Road Class	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
Adair Creek	Local	2.2	3	<1	2	2	1	2	2	1	1
	Ranch	0.4	1	<1	<1	<1	<1	<1	<1	<1	<1
	Unknown	6.0	8	1	6	5	4	5	6	1	3
Bangtail Creek	4x4	3.1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	0.8	1	<1	1	<1	<1	1	1	<1	<1
	Ranch	0.0	<1	0	<1	<1	<1	<1	<1	0	0
	Unknown	2.5	3	1	2	2	1	2	2	1	1
	US HWY	0.1	0	0	0	0	0	0	0	0	0
Canyon Creek	4x4	0.6	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	0.6	1	<1	1	<1	<1	1	1	<1	<1
	Unknown	6.7	7	1	5	6	3	5	5	1	3
Carrol Creek	Local	3.0	4	1	3	2	2	3	3	1	1
	MT HWY	0.8	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cottonwood Creek East	4x4	1.3	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	4.3	5	1	4	2	2	3	4	1	2
	Ranch	0.1	<1	<1	<1	<1	<1	0	<1	<1	<1
	Unknown	1.3	<1	<1	<1	1	<1	<1	<1	<1	<1
	US HWY	0.1	0	0	0	0	0	0	0	0	0
Cottonwood Creek West	4x4	0.0	0	0	0	0	0	0	0	0	0
	Local	4.5	6	1	5	3	3	5	5	1	3
	Unknown	1.6	1	<1	1	1	1	1	1	<1	1

Table D-5. Sediment contribution and potential reductions from unpaved roads by subwatershed and road class.

Subwatershed	Road Class	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
	US HWY	0.7	0	0	0	0	0	0	0	0	0
Daisy Dean Creek	4x4	0.4	0	0	0	0	0	0	0	0	0
	Local	4.5	6	1	4	3	3	4	4	1	2
	Unknown	1.3	1	<1	1	1	1	1	1	<1	1
Dry Creek	4x4	0.1	<1	0	<1	0	0	0	<1	<1	0
	Local	2.2	4	1	3	2	2	3	3	1	1
	MT HWY	0.7	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Unknown	1.4	2	<1	2	1	1	2	2	<1	1
Elk Creek	Local	4.9	9	1	6	4	4	6	6	1	3
	Ranch	0.1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Unknown	2.6	3	1	2	2	2	2	2	1	1
Falls Creek	Local	2.0	4	1	3	2	2	3	3	1	1
	Ranch	0.0	<1	0	<1	<1	<1	<1	<1	<1	<1
	Unknown	12.8	11	2	8	12	5	8	8	2	4
Horse Creek	Local	9.0	14	2	10	7	6	10	10	2	6
	Ranch	0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Unknown	3.1	2	<1	2	3	1	2	2	<1	1
Lower Brackett Creek	4x4	1.0	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	2.2	3	<1	2	1	1	2	2	<1	1
	Unknown	3.2	3	<1	2	3	1	2	2	1	1

Table D-5. Sediment contribution and potential reductions from unpaved roads by subwatershed and road class.

Subwatershed	Road Class	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
Lower Flathead Creek	4x4	0.7	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	3.8	6	1	5	3	3	4	5	1	3
	MT HWY	1.1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Ranch	0.3	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Unknown	0.7	<1	<1	<1	1	<1	<1	<1	<1	<1
	US HWY	0.2	0	0	0	0	0	0	0	0	0
Lower Shields River-Chicken Creek	4x4	1.1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	10.7	17	3	13	8	8	12	13	3	7
	Ranch	0.6	1	<1	1	1	<1	1	1	<1	<1
	Unknown	6.2	6	1	4	6	3	4	4	1	2
	US HWY	1.0	0	0	0	0	0	0	0	0	0
Lower Shields River-Crazyhead Creek	4x4	0.5	0	0	0	0	0	0	0	0	0
	Local	2.1	3	1	2	2	1	2	2	1	1
	Ranch	1.0	1	<1	1	1	1	1	1	<1	<1
	Unknown	6.6	6	1	5	6	3	5	5	1	3
	US HWY	1.0	0	0	0	0	0	0	0	0	0
Meadows Creek	4x4	4.4	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	2.1	4	1	3	2	2	3	3	1	2
	Ranch	0.0	0	0	0	<1	0	0	0	0	0
	Unknown	5.4	3	1	2	5	1	2	2	1	1
Middle Shields River-	4x4	1.2	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table D-5. Sediment contribution and potential reductions from unpaved roads by subwatershed and road class.

Subwatershed	**Road Class**	**Total contributing length within 200 ft of a stream**	**Existing Conditions**	**Settling Basins**	**Silt Fences**	**Upgrade All Contributing Road Surfaces to Gravel**	**Upgrade All Contributing Road Surfaces One Level**	**Upgrade All Contributing Road Surfaces One Level (no paving)**	**Repair All Rutted Road Surfaces to Original Condition**	**Apply Length Reducing BMPs at Crossings**	**Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)**
Antelope Creek											
	Local	6.0	9	1	7	4	4	6	7	2	4
	Ranch	0.3	<1	<1	<1	<1	<1	<1	<1	<1	<1
	US HWY	0.8	0	0	0	0	0	0	0	0	0
Middle Shields River-Spring Creek	4x4	0.4	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	1.5	3	<1	2	1	1	2	2	<1	1
	Ranch	0.1	0	0	0	<1	0	0	0	0	0
	Unknown	1.1	1	<1	1	1	1	1	1	<1	1
	US HWY	0.2	0	0	0	0	0	0	0	0	0
Muddy Creek	4x4	0.4	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	3.5	3	1	2	2	1	2	2	1	1
	Unknown	4.2	4	1	3	4	2	3	3	1	2
Porquepine Creek	4x4	1.8	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	6.6	8	1	6	4	4	6	6	1	3
	Ranch	0.3	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Unknown	1.8	2	<1	2	2	1	2	2	<1	1
Potter Creek	4x4	1.0	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	6.1	10	2	8	5	5	7	8	2	4
	Unknown	2.3	1	<1	1	2	<1	1	1	<1	<1
	US HWY	2.0	0	0	0	0	0	0	0	0	0
Rock Creek	4x4	0.8	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table D-5. Sediment contribution and potential reductions from unpaved roads by subwatershed and road class.

Subwatershed	Road Class	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
	Local	5.6	9	1	7	5	4	6	7	2	4
	Unknown	0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	US HWY	0.1	0	0	0	0	0	0	0	0	0
Upper Brackett Creek	4x4	0.3	<1	0	<1	0	<1	<1	<1	<1	<1
	Local	5.6	5	1	4	3	2	4	4	1	2
	MT HWY	0.6	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Ranch	0.8	<1	<1	1	1	<1	1	1	<1	<1
	Unknown	10.6	16	3	12	10	8	12	12	3	7
Upper Flathead Creek	Local	2.0	3	<1	2	1	1	2	2	<1	1
	MT HWY	0.1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Ranch	0.6	<1	<1	<1	1	<1	<1	<1	<1	<1
Upper Shields River-Antelope Creek	4x4	0.2	<1	0	<1	<1	<1	<1	<1	<1	<1
	Local	11.1	11	2	9	6	5	8	9	2	5
	Ranch	0.0	0	0	0	<1	0	0	0	0	0
	Unknown	1.4	1	<1	1	1	<1	1	1	<1	<1
Upper Shields River-Bennett Creek	4x4	1.9	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	4.4	8	1	6	4	4	6	6	2	3
	Ranch	0.3	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Unknown	11.7	11	2	8	11	5	8	8	3	4
Upper Shields River-	4x4	2.0	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table D-5. Sediment contribution and potential reductions from unpaved roads by subwatershed and road class.

Subwatershed	Road Class	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
Kavanaugh Creek											
	Local	5.4	7	1	6	4	3	5	6	1	3
	Ranch	0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Unknown	0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1
Willow Creek	4x4	5.5	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Local	3.4	4	1	3	2	2	3	3	1	2
	Ranch	0.1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Unknown	8.7	8	1	6	8	4	6	6	2	3
	US HWY	0.1	0	0	0	0	0	0	0	0	0

Table D-6. Sediment contribution and potential reductions from unpaved roads for the Shields River watershed by ownership, road class, and road orientation.

	Total contributing length within 200 ft of a stream	Existing Conditions	Settling Basins	Silt Fences	Upgrade All Contributing Road Surfaces to Gravel	Upgrade All Contributing Road Surfaces One Level	Upgrade All Contributing Road Surfaces One Level (no paving)	Repair All Rutted Road Surfaces to Original Condition	Apply Length Reducing BMPs at Crossings	Hybrid BMPs (60% length reduction and 40% upgrade of road surface 1 level)
Ownership										
Private/State	233.4	255	41	192	162	120	182	191	46	103
USFS	33.1	25	4	19	22	12	18	19	10	10
Road Class										
4x4	28.8	2	<1	1	1	1	1	2	2	1
Local	119.8	168	27	127	84	79	120	126	31	68
MT HWY	3.3	1	<1	1	1	1	1	1	<1	<1
Ranch	5.5	6	1	4	5	3	4	4	1	2
Unknown	103.7	103	17	78	94	48	73	77	22	42
US HWY	6.3	0	0	0	0	0	0	0	0	0
Road Orientation										
Parallel	109.6	4	1	3	3	2	3	3	1	2
Crossing	157.8	276	41	207	136	130	195	206	51	111
Shields River Watershed										
	267.4	280	46	211	185	131	199	210	56	113

APPENDIX E
SEDIMENT CONTRIBUTION FROM HILLSLOPE EROSION

Introduction

Upland sediment loading due to hillslope erosion was modeled using the USLE, and sediment delivery to the stream was predicted using a sediment delivery ratio. This model provided an assessment of existing sediment loading from upland sources and an assessment of potential sediment loading through the application of BMPs. For this evaluation the primary BMP evaluated includes the modification in upland management practices. When reviewing the results of the upland sediment load model it is important to note that a significant portion of the remaining sediment loads after BMPs in areas with grazing and/or silvicultural land-uses is also a component of the “natural upland load.” However, the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

A list of land cover classifications used in the USLE model is presented in **Table E-1**, along with a description of which land-use was associated with each cover type for the purposes of sediment source assessment and load allocations.

Table E-1. Land Cover Classifications for the USLE Model.

Land Cover Classifications	Land-use / Sediment Source
Bare Rock/Sand/Clay	Natural Source
Deciduous Forest	Natural Source
Evergreen Forest	Natural Source
Logging	Silviculture
Grasslands/Herbaceous	Grazing
Shrubland	Grazing
Pasture/Hay	Cropland
Fallow	Cropland
Small Grains	Cropland

Universal Soil Loss Equation (USLE)

The general form of the USLE has been widely used for erosion prediction in the U.S. and is presented in the National Engineering Handbook (1983) as:

(1) $A = RK(LS)CP$ (in tons $acre^{-1}$ $year^{-1}$)

where soil loss (A) is a function of the rainfall erosivity index (R), soil erodibility factor (K), overland flow slope and length (LS), crop management factor (C), and conservation practice factor (P) (Wischmeier and Smith 1978, Renard et al. 1991). The USLE estimates average soil loss from sheet and rill erosion, but does not estimate soil loss from gully erosion. USLE was selected for the Shields River watershed due to its relative simplicity, ease in parameterization, and the fact that it has been integrated into a number of other erosion prediction models. These include: (1) The Agricultural Nonpoint Source Model (AGNPS), (2) Areal Nonpoint Source Watershed Environment Response Simulation Model (ANSWERS), (3) Erosion Productivity Impact Calculator (EPIC), (4) Generalized Watershed Loading Functions (GWLF), and (5) the Soil Water Assessment Tool (SWAT) (Doe et. al. 1999). A detailed description of the general USLE model parameters is presented below.

The **R-factor** is an index that characterizes the effect of raindrop impact and rate of runoff associated with a rainstorm. It is a summation of the individual storm products of the kinetic energy in rainfall (hundreds of ft-tons acre-1 year-1) and the maximum 30-minute rainfall intensity (inches hour-1). The total kinetic energy of a storm is obtained by multiplying the kinetic energy per inch of rainfall by the depth of rainfall during each intensity period.

The **K-factor** or soil erodibility factor indicates the susceptibility of soil to resist erosion. It is derived by measurement of soil particle size (texture), percent organic matter, structure, and permeability. It is a measure of the average soil loss (tons acre-1 hundreds of ft-tons-1 per acre of rainfall intensity) from a particular soil in continuous fallow. The K-factor is based on experimental data from the standard SCS erosion plot that is 72.6 ft long with uniform slope of 9%.

The **LS-factor** is a function of the slope and overland flow length of the eroding slope or cell. For the purpose of computing the LS-value, slope is defined as the average land surface gradient. The flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. According to McCuen et. al. (1998), flow lengths are seldom greater that 400 or shorter than 20 feet.

The **C-factor** or crop management factor is the ratio of the soil eroded from a specific type of cover to that from a clean-tilled fallow under identical slope and rainfall. It integrates a number of factors that effect erosion including vegetative cover, plant litter, soil surface, and land management. The original C-factor of the USLE was experimentally determined for agricultural crops and has since been modified to include rangeland and forested cover. It is now referred to as the vegetation management factor (VM) for non-agricultural settings (Brooks et. al. 1997).

Three different kinds of effects are considered in determination of the VM-factor. These include: (1) Canopy cover effects; (2) effects of low-growing vegetal cover, mulch, and litter; and (3) rooting structure. A set of metrics has been published by the Soil Conservation Service (SCS) for estimation of the VM-factors for grazed and undisturbed woodlands, permanent pasture, rangeland, and idle land. Although these are quite helpful for the Shields River watershed, Brooks et. al. (1997) cautions that more work has been carried out in determining the agriculturally based C-factors than rangeland/forest VM-factors. Because of this, the results of the interpretation should be used with discretion.

The **P-factor** (conservation practice factor) is a function of the interaction of the supporting land management practice and slope. It incorporates the use of erosion control practices such as strip-cropping, terracing, and contouring and is applicable only to agricultural lands. Values of the P-factor compare straight-row (up-slope down-slope) farming practices with that of certain agriculturally-based conservation practices.

Modeling Approach
Sediment delivery from hillslope erosion was estimated using a USLE based model to predict soil loss, along with a sediment delivery ratio (SDR) to predict sediment delivered to the stream. This USLE based model is implemented as a watershed scale, grid format, GIS model using ArcView v 9.0 GIS software.

Desired results from the modeling effort include the following: (1) Annual sediment load from each of the water quality limited segments on the state's 303(d) List and (2) the mean annual source distribution from each land category type. Based on these considerations, a GIS-modeling approach (USLE 3-D) was formulated to facilitate database development and manipulation, provide spatially explicit output, and supply output display for the modeling effort.

Modeling Scenarios
Two upland management scenarios were proposed as part of the Shields River modeling project. They include: (1) An existing condition scenario that considers the current land use cover and management practices in the watershed and (2) an improved grazing and cover management scenario.

Erosion was differentiated into two source categories for each scenario: (1) Natural erosion that occurs on the time scale of geologic processes and (2) anthropogenic erosion that is accelerated by human-caused activity. A similar classification is presented as part of the National Engineering Handbook Chapter 3 - Sedimentation (USDA, 1983). Differentiation is necessary for TMDL planning.

Data Sources
The USLE-3D model was parameterized using a number of published data sources. These include information from (1) USGS, (2) Spatial Climate Analysis Service (SCAS), and (3) Soil Conservation Service (SCS). Additionally, local information regarding specific land use management and cropping practices was acquired from the Montana Agricultural Extension Service (MAES) and the NRCS. Specific GIS coverages used in the modeling effort included the following:

R – Rainfall factor. Grid data of this factor was obtained from the NRCS and is based on Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data. PRISM precipitation data is derived from weather station precipitation records, interpolated to a gridded landscape coverage by a method (developed by the Spatial Climate Analysis Service of Oregon State University) which accounts for the effects of elevation on precipitation patterns.

K – Soil erodibility factor. Polygon data of this factor were obtained from the NRCS General Soil Map (STATSGO) database. The USLE K factor is a standard component of the STATSGO soil survey. STATSGO soils polygon data were summarized and interpolated to grid format for this analysis.

LS – Slope length and slope factors. These factors were derived from 30m USGS digital elevation model (DEM) grid data, interpolated to a 10m pixel.

C – Cropping factor. This factor was estimated using the National Land Cover Dataset (NLCD), using C-factor interpretations provided by the NRCS and refined by Montana DEQ using SCS C-factor tables (Brooks et al. 1997). C-factors are intended to be conservatively representative of conditions in the Shields Valley.

P – Management practices factor. This factor was set to 1, as consultation with the NRCS State Agronomist suggests that this value is the most appropriate representation of current management practices in the Shields River Watershed (i.e. no use of contour plowing, terracing, etc).

Method

An appropriate grid for each factors' values was created, giving full and appropriate consideration to proper stream network delineation, grid cell resolution, etc. A computer model was built using ArcView Model Builder to derive the five factors from model inputs, multiply the five factors, and arrive at a predicted sediment production for each grid cell. The model also derived a sediment delivery ratio for each cell, and reduced the predicted sediment production by that factor to estimate sediment delivered to the stream network.

Specific parameterization of the USLE factors was performed as follows:

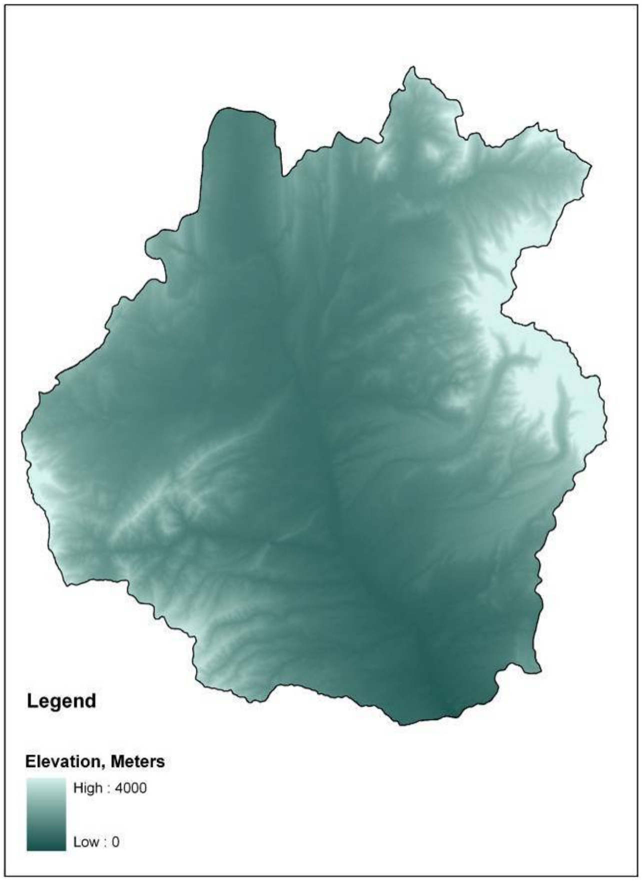

Figure E-1. Digital Elevation Model (DEM) of the Shields River Watershed, Prepared for Hydrologic Analysis

Shields DEM

The DEM for the Shields River Watershed was the foundation for developing the LS factor, for defining the extent of the bounds of the analysis area (the Shields River Watershed), and for delineating the area within the outer bounds of the analysis for which the USLE model is not valid (i.e. the concentrated flow channels of the stream network). The USGS 30m DEM (level 2) for the Shields was used for these analyses. First the DEM was interpolated to a 10m analytic grid cell to render the delineated stream network more representative of the actual size of Shields River watershed streams and to minimize resolution dependent stream network anomalies. The resulting interpolated 10m was then subjected to standard hydrologic preprocessing, including the filling of sinks to create a positive drainage condition for all areas of the watershed.

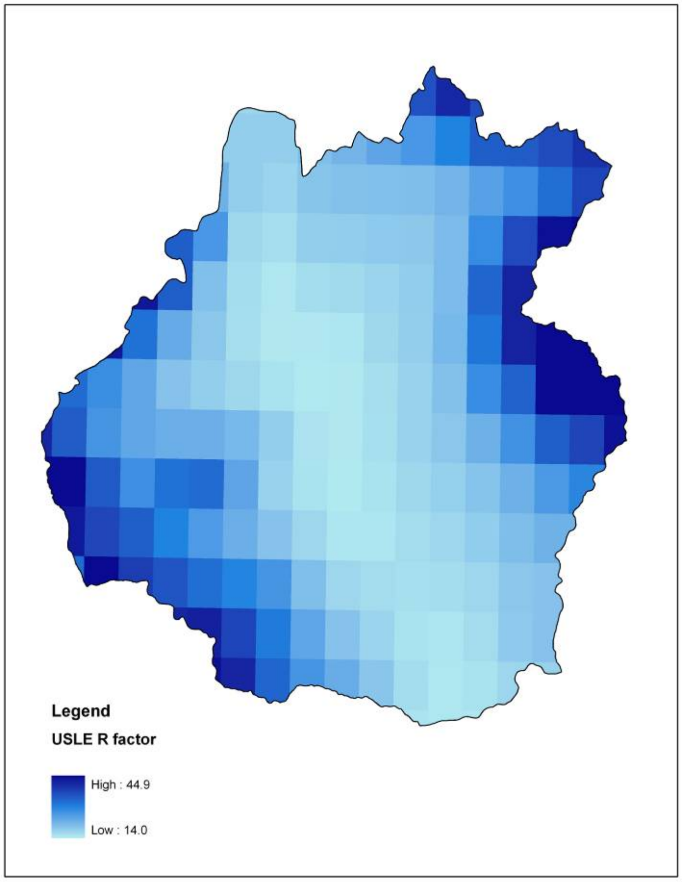

Figure E-2. ULSE R Factor for the Shields Watershed

R-Factor

The rainfall and runoff factor grid was prepared by the Spatial Climate Analysis Service (SCAS) of Oregon State University at 4 km grid cell resolution. For the purposes of this analysis, the SCAS R-factor grid was reprojected to Montana State Plane Coordinates (NAD83, meters), resampled to a 10m analytic cell size and clipped to the extent of the Shields Watershed, to match the project's standard grid definition.

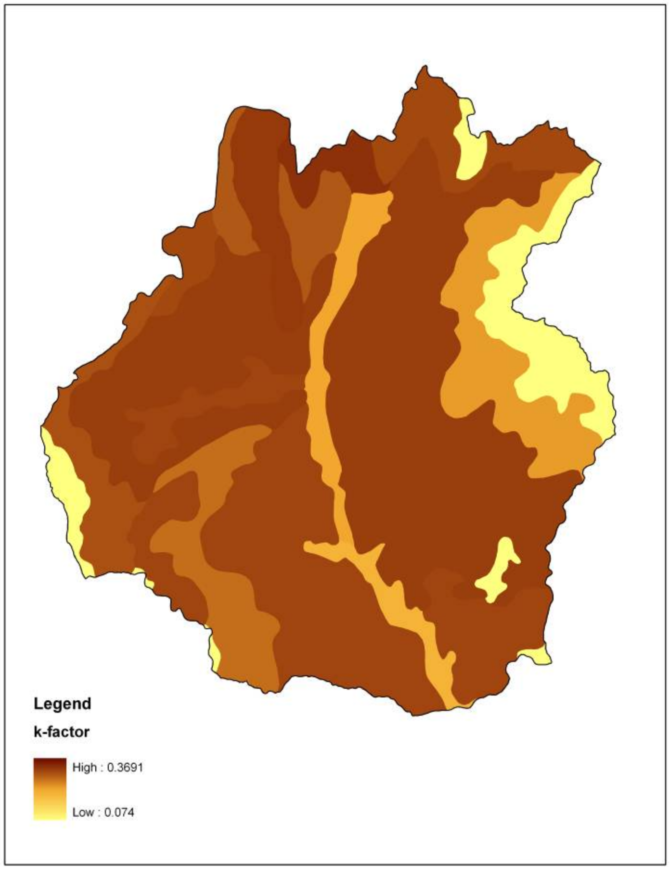

Figure E-3. ULSE K factor for the Shields Watershed.

<u>K-Factor</u>
The soil erodibility factor grid was compiled from 1:250K STATSGO data, as published by the NRCS. STATSGO database tables were queried to calculate a component weighted K value for all surface layers, which was then summarized by individual map unit. The map unit K values were then joined to a GIS polygon coverage of the STATSGO map units, and the polygon coverage was converted to a 10m analytic grid for use in this analysis.

<u>LS- Factor</u>
The equation used for calculating the slope length and slope factor was that given in the updated definition of USLE, as published in USDA handbook #537:

$$LS = (\lambda/72.6)^m \, (65.41 \sin^2\theta + 4.56 \sin\theta + 0.065)$$

Where:

λ = slope length in feet. This value was determined by applying GIS based surface analysis procedures to the Shields watershed DEM, calculating total upslope length for each 10m grid cell, and converting the results to feet from meters. In accordance with research that indicates that, in practice, the slope length rarely exceeds 400 ft, λ was limited to that maximum value.

θ = cell slope cell slope as calculated by GIS based surface analysis procedures from the Shields watershed DEM

m = 0.5 if percent slope of the cell >= 5
= 0.4 if percent slope of the cell >= 3.5 AND < 5
= 0.3 if percent slope of the cell >= 1 AND < 3.5
= 0.2 if percent slope of the cell < 1

The LS factor grid was calculated from individual grids computed for each of these sub factors, using a simple ArcView Model Builder script.

C-Factor

The cover management factor of the USLE reflects the varying degree of erosion protection that results from different cover types. It integrates a number of factors including vegetative cover, plant litter, soil surface, and land management. For the purpose of this study, the C-factor is the only USLE parameter that can be altered by the influence of human activity. Based on this, C-factors were estimated for the existing condition and improved management scenarios (**Table E-2**). The C-factor change for agricultural cover types between management scenarios corresponds to increases in the percent of land cover that are achievable through the application of various best management practices (**Table E-3**). For natural sources (i.e. bare rock, deciduous forest, and evergreen forest), the C-factor is the same for both scenarios. A C-factor slightly higher than deciduous/evergreen forest was used for logged areas because logging intensity within the watershed is low and because practices, such as riparian clearcutting, that tend to produce high sediment yields have not been used since at least 1991, when the Montana SMZ Law was enacted. Additionally, the USLE model is intended to reflect long-term average sediment yield, and while a sediment pulse typically occurs in the first year after logging, sediment production after the first year rapidly declines (Rice et al. 1972; Elliot and Robichaud 2001; Elliot 2006). The logging C-factor is the same for both management scenarios to indicate that logging will continue sporadically on public and private land within the watershed and will produce sediment at a rate slightly higher than an undisturbed forest. This is not intended to imply that additional best management practices beyond those in the SMZ law should not be used for logging activities.

C-factors were defined spatially through use of a modified version of the Anderson land cover classification (1976) and the 1992 30m Landsat Thematic Mapper (TM) multi-spectral imaging (NLDC, 1992) (**Figure E-4**). C-factor values were assigned globally to each land type and range from 0.001 to 1.0. These data were reprojected to Montana State plane projection/coordinate system and resampled to the standard 10m grid. No field efforts were initiated as part of this study to refine C-factor estimation for the watershed.

Table E-2. Shields River C-Factor; Existing and Improved Management Conditions

NLCD Code	Description	C-Factor	
		Existing Condition	Improved Management Condition
31	Bare Rock/Sand/Clay	0.001	0.001
41	Deciduous Forest	0.003	0.003
42	Evergreen Forest	0.003	0.003
51	Shrubland	0.046	0.031
71	Grasslands Herbaceous	0.042	0.035
81	Pasture /Hay	0.020	0.013
83	Small Grains	0.240	0.015
84	Fallow	0.440	0.120
N/A	Logging	0.006	0.006

Table E-3. Changes in Percent Ground Cover for Agricultural Land Cover Types between Existing and Improved Management Condition.

Land Cover	Existing % ground cover	Improved % ground cover
Shrubland	55	65
Grasslands Herbaceous	55	65
Pasture /Hay	65	75
Small Grains	20	40
Fallow	5	35

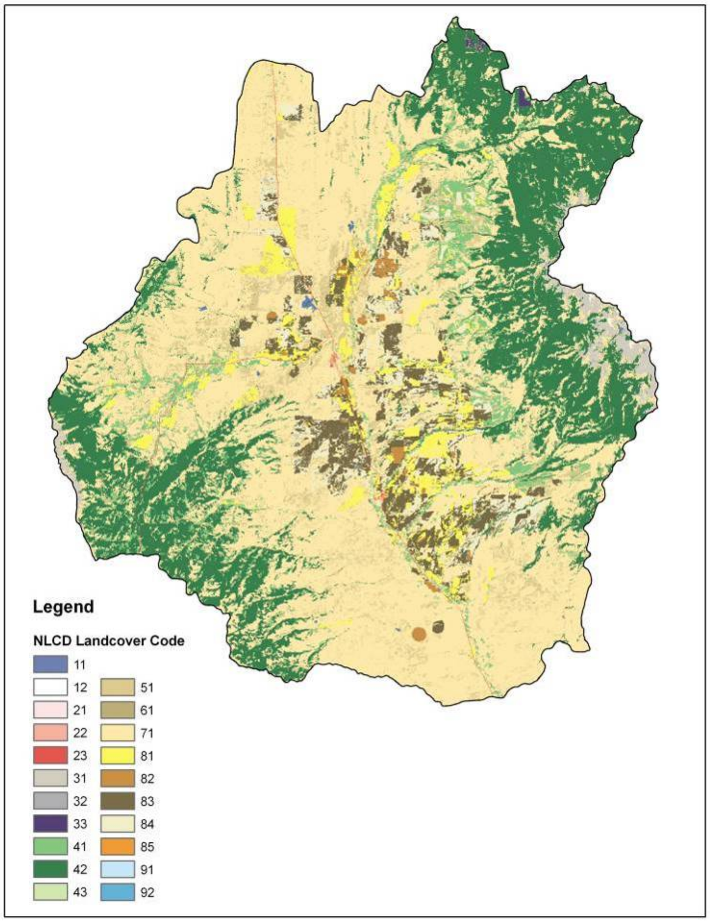

Figure E-4. NLCD Landcover for the Shields Watershed

<u>NLCD – Landcover</u>
In general, the land use classification of the NLCD was accepted as is, without ground truthing of original results or correction of changes over the time since the NLCD image was taken. Given that we are looking for watershed and subwatershed scale effects, this was considered to be a reasonable assumption given the relative simplicity of the land use mix in the Shields Valley, and the relative stability of that land use over the 14 years since the Landsat image that the NLCD is based on was shot. One adjustment was made to the NLCD, however. That adjustment was to quantify the amount of logging that has occurred since 1992, and to also identify areas that are reforesting over that same period. As with other land uses in the valley, logging is a stable land use, but it is a land use that causes a land cover change that may effect sediment production.

Adjustment for logging and reforestation was accomplished by comparing the 1992 NLCD grid for the Shields Watershed with the 2005 NAIP aerial photography. Areas which were coded as a forest type (41 or 42) on the NLCD were recoded to 'logged' if:

- They appeared to be otherwise (typically bare ground, grassland, or shrubland) on the NAIP photos, and

- There were indications of indicated logging activity (proximity to forest or logging roads, appearance of stands, etc).

Sediment Delivery Ratio

A SDR factor was created for each grid cell, based on the relationship between the distance from the delivery point to the stream established by Dube, Megahan & McCalmon in their development of the WARSEM road sediment model for the State of Washington. This relationship was developed by integrating the results of several previous studies (principally those of Megehan and Ketchison) which examined sediment delivery to streams downslope of forest roads. They found that the proportion of sediment production that is ultimately delivered to streams declines with distance from the stream (**Table E-4**) with the balance of the sediment being deposited between the point of production and the stream. We believe the use of this relationship to develop a SDR for a USLE based model is a conservative (i.e. tending toward the high end of the range of reasonable values) estimate of sediment delivery from hillslope erosion, especially in light of the fact that the USLE methodology does not account for gully erosion. The SDR factor was applied to the results of the USLE model to estimate sediment delivered from hill slope sources, by calculating the distance from each cell to the nearest stream channel, and multiplying the sediment production of that cell by the corresponding distance based percentage of delivery.

Table E-4. The Percent of Sediment Delivered by Distance from a Water Body

Distance from Culvert (ft)	Percent of Total Eroded Sediment Delivered
0	100
35	70
70	50
105	35
140	25
175	18
210	10
245	4
280	3
315	2
350	1

Although the SDR factor accounts for the distance of sediment production cells from the stream channel, it does not account for riparian condition and the ability of riparian vegetation to filter out sediment and prevent it from entering the stream. Depending on the vegetation type and buffer width, healthy riparian buffers can remove anywhere from 50-90% of sediment (Castelle and Johnson 2000; Hook 2003; DEQ 2007). Therefore, the USLE model used for source assessment may have overestimated existing loads and underestimated potential reductions due to hillslope erosion.

Results

Figures E-5 and E-6 present the USLE based hillslope model's prediction of existing and potential conditions graphically for the entire Shields River watershed. **Table E-5** contains the estimated existing and potential sediment load from hillslope erosion for each 6th code HUC and the entire Shields River watershed, and it also contains loads normalized by the contributing watershed area. **Table E-6** contains the estimated existing and potential sediment load from

hillslope erosion for each 6th code HUC and the Shields River watershed broken out by land cover type.

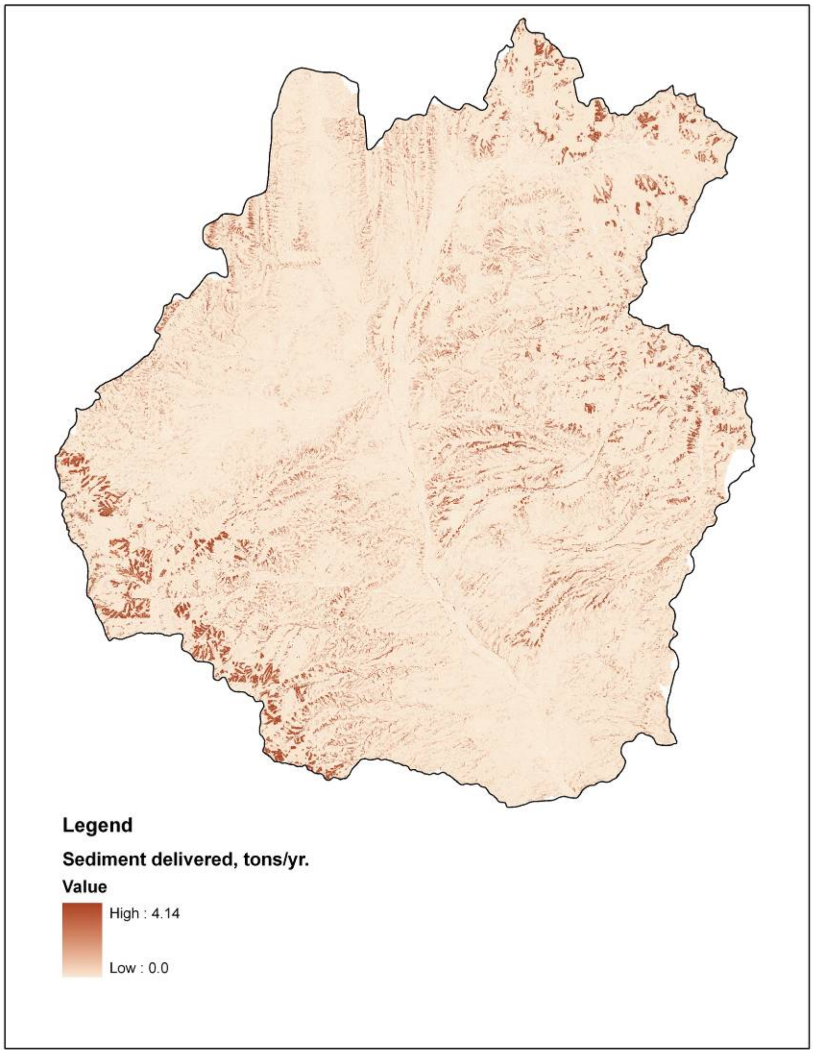

Figure E-5. Estimated Sediment Delivery from Hill Slopes, Existing Conditions

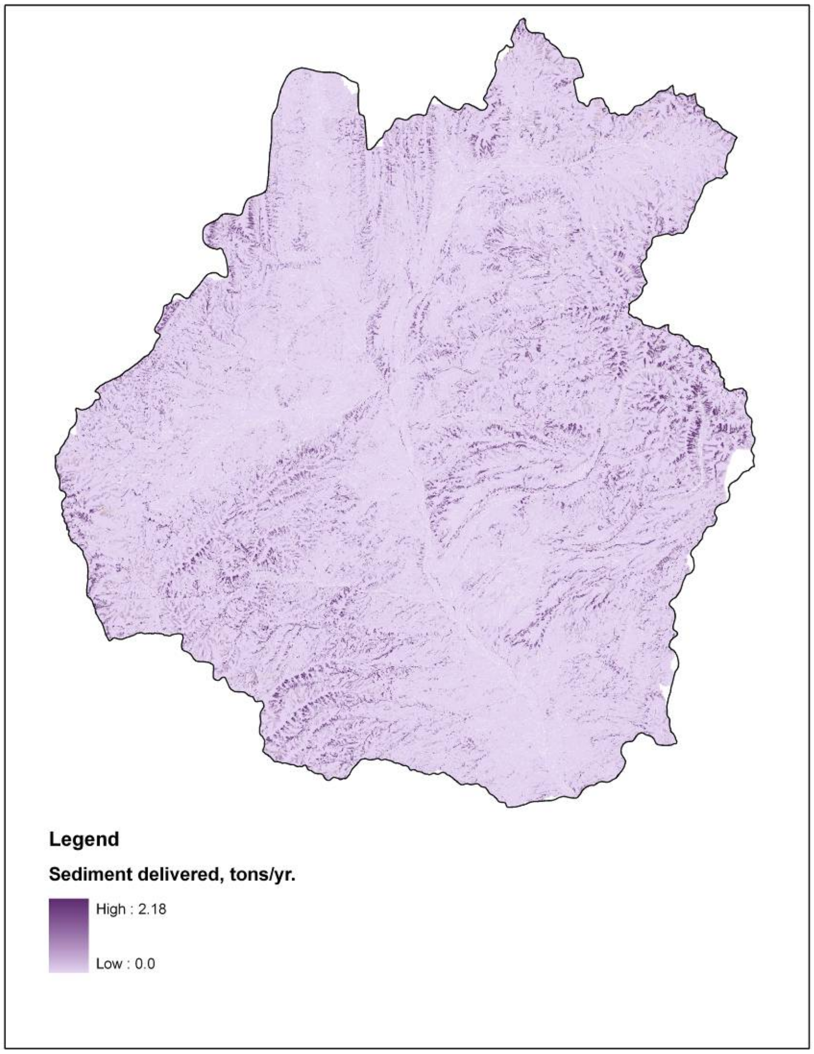

Figure E-6. Estimated Sediment Delivery from Hill Slopes, BMP Conditions

Table E-5. Total and Normalized Existing and Potential Sediment Loads from Upland Erosion for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

6th Code HUC Subwatershed	Acres	Existing Load (tons/yr)	Potential Load (tons/yr)	Normalized Existing Load (tons/acre/yr)	Normalized Potential Load (tons/acre/yr)
Adair Creek	13387	2100	1700	0.157	0.127
Bangtail Creek	8613	5600	2800	0.648	0.319
Canyon Creek	14004	5900	2700	0.421	0.193
Carrol Creek	19168	4600	2500	0.239	0.131
Cottonwood Creek East	23497	10700	6800	0.455	0.288
Cottonwood Creek West	20766	4600	3600	0.223	0.171
Daisy Dean Creek	9551	2900	1900	0.306	0.201
Dry Creek	13058	1500	1200	0.119	0.090
Elk Creek	16912	4200	1800	0.249	0.107
Falls Creek	16531	3600	2100	0.217	0.128
Horse Creek	24839	8700	4600	0.350	0.187

Table E-5. Total and Normalized Existing and Potential Sediment Loads from Upland Erosion for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

6th Code HUC Subwatershed	Acres	Existing Load (tons/yr)	Potential Load (tons/yr)	Normalized Existing Load (tons/acre/yr)	Normalized Potential Load (tons/acre/yr)
Lower Brackett Creek	14322	3200	2600	0.226	0.182
Lower Flathead Creek	20238	2500	1900	0.124	0.092
Lower Shields River-Chicken Creek	24117	6900	1900	0.285	0.078
Lower Shields River-Crazyhead Creek	21462	2300	1900	0.109	0.088
Meadows Creek	15909	4200	2200	0.265	0.137
Middle Shields River-Antelope Creek	35868	12900	4900	0.359	0.135
Middle Shields River-Spring Creek	9729	1900	500	0.191	0.053
Muddy Creek	13461	2800	2100	0.208	0.158
Porquepine Creek	15842	3200	1700	0.203	0.106
Potter Creek	**37476**	**5700**	**3700**	**0.151**	**0.100**
Rock Creek	33877	13700	10200	0.404	0.302
Upper Brackett Creek	27582	15400	6800	0.558	0.247
Upper Flathead Creek	14638	3100	2500	0.214	0.174
Upper Shields River-Antelope Creek	15179	2700	1900	0.178	0.123
Upper Shields River-Bennett Creek	31894	10600	5100	0.331	0.159
Upper Shields River-Kavanaugh Creek	14567	2400	1900	0.165	0.132
Willow Creek	19872	8800	5500	0.444	0.278
Total Shields Watershed	**546359**	**157000**	**89000**	**0.287**	**0.163**

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Adair Creek	Deciduous Forest	<10	<10
Adair Creek	Evergreen Forest	10	10
Adair Creek	Shrubland	280	190
Adair Creek	Grasslands/Herbaceous	1800	1500
Adair Creek	Small Grains	<10	0
Bangtail Creek	Bare Rock/Sand/Clay	<10	<10
Bangtail Creek	Deciduous Forest	20	20
Bangtail Creek	Evergreen Forest	210	210
Bangtail Creek	Shrubland	630	380
Bangtail Creek	Grasslands/Herbaceous	4630	2070
Bangtail Creek	Small Grains	20	<10
Bangtail Creek	Fallow	<10	0
Bangtail Creek	Logged	80	80
Canyon Creek	Deciduous Forest	20	20
Canyon Creek	Evergreen Forest	250	250
Canyon Creek	Shrubland	650	400
Canyon Creek	Grasslands/Herbaceous	4760	1900
Canyon Creek	Small Grains	80	<10
Canyon Creek	Logged	120	120
Carrol Creek	Commercial/Industrial/Transportation	<10	<10
Carrol Creek	Bare Rock/Sand/Clay	40	40
Carrol Creek	Deciduous Forest	30	30
Carrol Creek	Evergreen Forest	370	370
Carrol Creek	Shrubland	670	350
Carrol Creek	Grasslands/Herbaceous	3230	1490
Carrol Creek	Pasture/Hay	30	20
Carrol Creek	Logged	220	220
Cottonwood Creek East	Bare Rock/Sand/Clay	140	140
Cottonwood Creek East	Deciduous Forest	40	40
Cottonwood Creek East	Evergreen Forest	960	960
Cottonwood Creek East	Shrubland	1260	840
Cottonwood Creek East	Grasslands/Herbaceous	5150	4210
Cottonwood Creek East	Pasture/Hay	90	60
Cottonwood Creek East	Small Grains	1480	90
Cottonwood Creek East	Fallow	1570	430
Cottonwood Creek East	Logged	10	10
Cottonwood Creek West	Deciduous Forest	10	10
Cottonwood Creek West	Evergreen Forest	30	30
Cottonwood Creek West	Shrubland	440	300
Cottonwood Creek West	Grasslands/Herbaceous	3770	3140
Cottonwood Creek West	Pasture/Hay	40	20
Cottonwood Creek West	Small Grains	180	10
Cottonwood Creek West	Fallow	170	50
Daisy Dean Creek	Bare Rock/Sand/Clay	<10	<10
Daisy Dean Creek	Deciduous Forest	10	10
Daisy Dean Creek	Evergreen Forest	90	90

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Daisy Dean Creek	Shrubland	370	250
Daisy Dean Creek	Grasslands/Herbaceous	1620	1350
Daisy Dean Creek	Pasture/Hay	10	<10
Daisy Dean Creek	Small Grains	60	<10
Daisy Dean Creek	Fallow	760	210
Dry Creek	Deciduous Forest	20	20
Dry Creek	Evergreen Forest	40	40
Dry Creek	Shrubland	300	200
Dry Creek	Grasslands/Herbaceous	1070	890
Dry Creek	Pasture/Hay	<10	<10
Dry Creek	Small Grains	60	<10
Dry Creek	Fallow	60	20
Elk Creek	Bare Rock/Sand/Clay	<10	<10
Elk Creek	Deciduous Forest	20	20
Elk Creek	Evergreen Forest	230	230
Elk Creek	Shrubland	300	200
Elk Creek	Grasslands/Herbaceous	870	720
Elk Creek	Pasture/Hay	20	10
Elk Creek	Row Crops	<10	<10
Elk Creek	Small Grains	620	40
Elk Creek	Fallow	2140	590
Falls Creek	Deciduous Forest	10	10
Falls Creek	Evergreen Forest	80	80
Falls Creek	Shrubland	470	320
Falls Creek	Grasslands/Herbaceous	1630	1360
Falls Creek	Pasture/Hay	10	<10
Falls Creek	Small Grains	220	10
Falls Creek	Fallow	1160	320
Horse Creek	Bare Rock/Sand/Clay	<10	<10
Horse Creek	Deciduous Forest	50	50
Horse Creek	Evergreen Forest	410	410
Horse Creek	Shrubland	710	470
Horse Creek	Grasslands/Herbaceous	3500	2810
Horse Creek	Pasture/Hay	70	50
Horse Creek	Small Grains	1150	70
Horse Creek	Fallow	2770	760
Horse Creek	Logged	30	30
Lower Brackett Creek	Deciduous Forest	10	10
Lower Brackett Creek	Evergreen Forest	50	50
Lower Brackett Creek	Shrubland	540	360
Lower Brackett Creek	Grasslands/Herbaceous	2600	2170
Lower Brackett Creek	Pasture/Hay	<10	<10
Lower Brackett Creek	Small Grains	30	<10
Lower Brackett Creek	Fallow	<10	<10
Lower Flathead Creek	Deciduous Forest	20	20
Lower Flathead Creek	Evergreen Forest	170	170
Lower Flathead Creek	Mixed Forest	0	0

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Lower Flathead Creek	Shrubland	600	410
Lower Flathead Creek	Grasslands/Herbaceous	1480	1200
Lower Flathead Creek	Pasture/Hay	50	30
Lower Flathead Creek	Small Grains	150	<10
Lower Flathead Creek	Fallow	40	10
Lower Shields River-Chicken Creek	Deciduous Forest	<10	<10
Lower Shields River-Chicken Creek	Evergreen Forest	10	10
Lower Shields River-Chicken Creek	Shrubland	200	140
Lower Shields River-Chicken Creek	Grasslands/Herbaceous	750	630
Lower Shields River-Chicken Creek	Pasture/Hay	70	40
Lower Shields River-Chicken Creek	Small Grains	2550	160
Lower Shields River-Chicken Creek	Fallow	3300	900
Lower Shields River-Crazyhead Creek	Deciduous Forest	<10	<10
Lower Shields River-Crazyhead Creek	Evergreen Forest	<10	<10
Lower Shields River-Crazyhead Creek	Shrubland	250	170
Lower Shields River-Crazyhead Creek	Grasslands/Herbaceous	2060	1720
Lower Shields River-Crazyhead Creek	Small Grains	30	<10
Lower Shields River-Crazyhead Creek	Fallow	<10	<10
Meadows Creek	Bare Rock/Sand/Clay	<10	<10
Meadows Creek	Deciduous Forest	30	30
Meadows Creek	Evergreen Forest	580	580
Meadows Creek	Shrubland	650	310
Meadows Creek	Grasslands/Herbaceous	2830	1140
Meadows Creek	Logged	130	130
Middle Shields River-Antelope Creek	Deciduous Forest	30	30
Middle Shields River-Antelope Creek	Evergreen Forest	100	100
Middle Shields River-Antelope Creek	Shrubland	670	450
Middle Shields River-Antelope Creek	Grasslands/Herbaceous	3160	2630
Middle Shields River-Antelope Creek	Pasture/Hay	70	50
Middle Shields River-Antelope Creek	Row Crops	<10	<10
Middle Shields River-Antelope Creek	Small Grains	4050	250
Middle Shields River-Antelope Creek	Fallow	4790	1310
Middle Shields River-Spring Creek	Deciduous Forest	<10	<10
Middle Shields River-Spring Creek	Shrubland	60	40
Middle Shields River-Spring Creek	Grasslands/Herbaceous	210	170
Middle Shields River-Spring Creek	Pasture/Hay	50	30
Middle Shields River-Spring Creek	Small Grains	730	50
Middle Shields River-Spring Creek	Fallow	810	220
Muddy Creek	Deciduous Forest	20	20
Muddy Creek	Evergreen Forest	70	70
Muddy Creek	Shrubland	350	240
Muddy Creek	Grasslands/Herbaceous	2100	1750
Muddy Creek	Pasture/Hay	<10	<10
Muddy Creek	Small Grains	140	<10
Muddy Creek	Fallow	110	30
Porquepine Creek	Deciduous Forest	30	30
Porquepine Creek	Evergreen Forest	100	100

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Porquepine Creek	Shrubland	480	320
Porquepine Creek	Grasslands/Herbaceous	1010	840
Porquepine Creek	Pasture/Hay	30	20
Porquepine Creek	Small Grains	280	20
Porquepine Creek	Fallow	1290	350
Potter Creek	**Deciduous Forest**	<10	<10
Potter Creek	**Evergreen Forest**	**10**	**10**
Potter Creek	**Shrubland**	**650**	**440**
Potter Creek	**Grasslands/Herbaceous**	**3530**	**2940**
Potter Creek	**Pasture/Hay**	**50**	**30**
Potter Creek	**Small Grains**	**400**	**30**
Potter Creek	**Fallow**	**1030**	**280**
Rock Creek	Bare Rock/Sand/Clay	250	250
Rock Creek	Deciduous Forest	70	70
Rock Creek	Evergreen Forest	1120	1120
Rock Creek	Shrubland	2400	1620
Rock Creek	Grasslands/Herbaceous	8310	6830
Rock Creek	Pasture/Hay	40	30
Rock Creek	Small Grains	430	30
Rock Creek	Fallow	1030	280
Rock Creek	Logged	20	20
Upper Brackett Creek	Commercial/Industrial/Transportation	<10	<10
Upper Brackett Creek	Bare Rock/Sand/Clay	30	30
Upper Brackett Creek	Deciduous Forest	170	170
Upper Brackett Creek	Evergreen Forest	1050	1050
Upper Brackett Creek	Shrubland	2600	1360
Upper Brackett Creek	Grasslands/Herbaceous	11040	3740
Upper Brackett Creek	Pasture/Hay	<10	<10
Upper Brackett Creek	Logged	480	480
Upper Flathead Creek	Bare Rock/Sand/Clay	40	40
Upper Flathead Creek	Deciduous Forest	30	30
Upper Flathead Creek	Evergreen Forest	160	160
Upper Flathead Creek	Shrubland	510	340
Upper Flathead Creek	Grasslands/Herbaceous	2240	1820
Upper Flathead Creek	Pasture/Hay	10	<10
Upper Flathead Creek	Logged	160	160
Upper Shields River-Antelope Creek	Deciduous Forest	<10	<10
Upper Shields River-Antelope Creek	Evergreen Forest	<10	<10
Upper Shields River-Antelope Creek	Shrubland	360	250
Upper Shields River-Antelope Creek	Grasslands/Herbaceous	1870	1560
Upper Shields River-Antelope Creek	Pasture/Hay	20	20
Upper Shields River-Antelope Creek	Row Crops	<10	<10
Upper Shields River-Antelope Creek	Small Grains	360	20
Upper Shields River-Antelope Creek	Fallow	80	20
Upper Shields River-Bennett Creek	Bare Rock/Sand/Clay	60	60
Upper Shields River-Bennett Creek	Deciduous Forest	20	20
Upper Shields River-Bennett Creek	Evergreen Forest	1560	1560

Table E-6. Existing and Potential Sediment Delivery by Land Cover Type for Each 6th Code HUC (Sub-Watershed) and for the Shields River Watershed (i.e. all HUCs)
Potter Creek and the Shields River watershed are bolded.

Watershed	NLCD LABEL	Existing Condition (tons/year)	Potential Condition (tons/year)
Upper Shields River-Bennett Creek	Shrubland	1030	530
Upper Shields River-Bennett Creek	Grasslands/Herbaceous	7660	2650
Upper Shields River-Bennett Creek	Logged	250	250
Upper Shields River-Kavanaugh Creek	Deciduous Forest	20	20
Upper Shields River-Kavanaugh Creek	Evergreen Forest	70	70
Upper Shields River-Kavanaugh Creek	Shrubland	330	220
Upper Shields River-Kavanaugh Creek	Grasslands/Herbaceous	1890	1570
Upper Shields River-Kavanaugh Creek	Pasture/Hay	30	20
Upper Shields River-Kavanaugh Creek	Small Grains	10	<10
Upper Shields River-Kavanaugh Creek	Fallow	60	20
Willow Creek	Bare Rock/Sand/Clay	<10	<10
Willow Creek	Deciduous Forest	30	30
Willow Creek	Evergreen Forest	340	340
Willow Creek	Shrubland	1070	670
Willow Creek	Grasslands/Herbaceous	7160	4280
Willow Creek	Pasture/Hay	10	<10
Willow Creek	Small Grains	10	<10
Willow Creek	Fallow	<10	<10
Willow Creek	Logged	190	190
Shields Watershed	**Bare Rock/Sand/Clay**	**570**	**570**
Shields Watershed	**Deciduous Forest**	**730**	**730**
Shields Watershed	**Evergreen Forest**	**8090**	**8090**
Shields Watershed	**Shrubland**	**18850**	**11750**
Shields Watershed	**Grasslands/Herbaceous**	**91920**	**59060**
Shields Watershed	**Pasture/Hay**	**720**	**470**
Shields Watershed	**Row Crops**	<10	<10
Shields Watershed	**Small Grains**	**13040**	**820**
Shields Watershed	**Fallow**	**21190**	**5780**
Shields Watershed	**Logged**	**1680**	**1680**

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APPENDIX F
SEDIMENT CONTRIBUTION FROM STREAMBANK EROSION

Approach

Application of the BEHI method (Rosgen 2001) allowed estimation of sediment delivery from stream banks. This methodology predicts stream erosion rate to sampled stream banks, creating an extrapolation factor from the results, and applying this extrapolation factor to the total length of streams in each 6th code HUC sub-watershed (as modified to break out 303d listed streams). The BEHI method is an empirical technique based on bank erosion rate data recorded in the Lamar River watershed of Yellowstone National Park and a variety of streams in the Colorado Front Range. Rosgen (2001) found a statistically significant relationship between the BEHI rating and bank erosion rate in the absence of any data representing the near bank shear stress. The method allows for prediction of bank erosion rates based on BEHI ratings developed from data collected in the field.

Methods

Field data collection

Field data for BEHI parameters were collected in the fall of 2004 following the quality assurance project plan (Confluence 2005). Parameters such as length of eroding bank, height of eroding bank, bankfull height, root depth, root density, bank angle, and surface protection (**Figure F-1**) were collected for each eroding bank within each assessment reach according to methods outlined by Rosgen (2004). Locations of sample reaches are shown in **Figure F-2**.

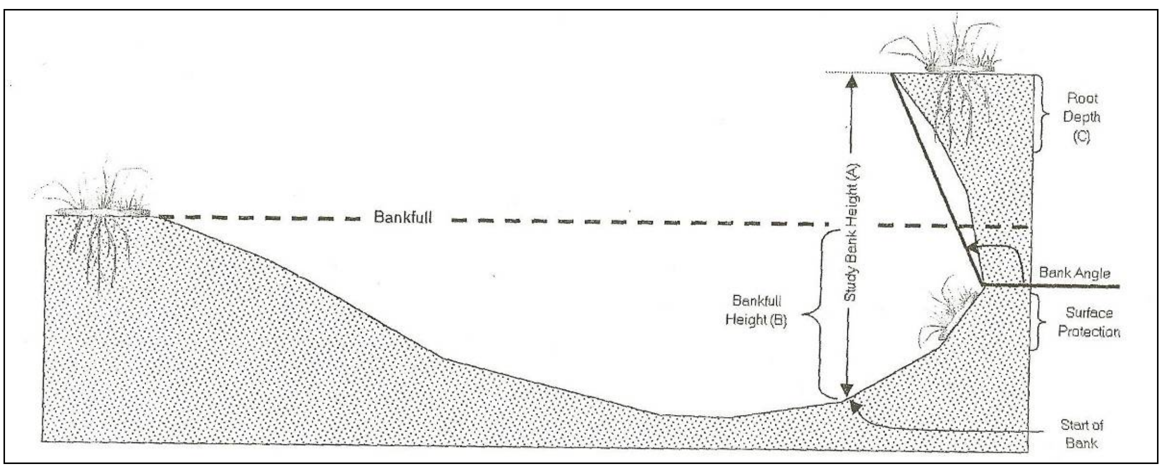

Figure F-1. BEHI Field Data Collection Methods
(Rosgen 2004)

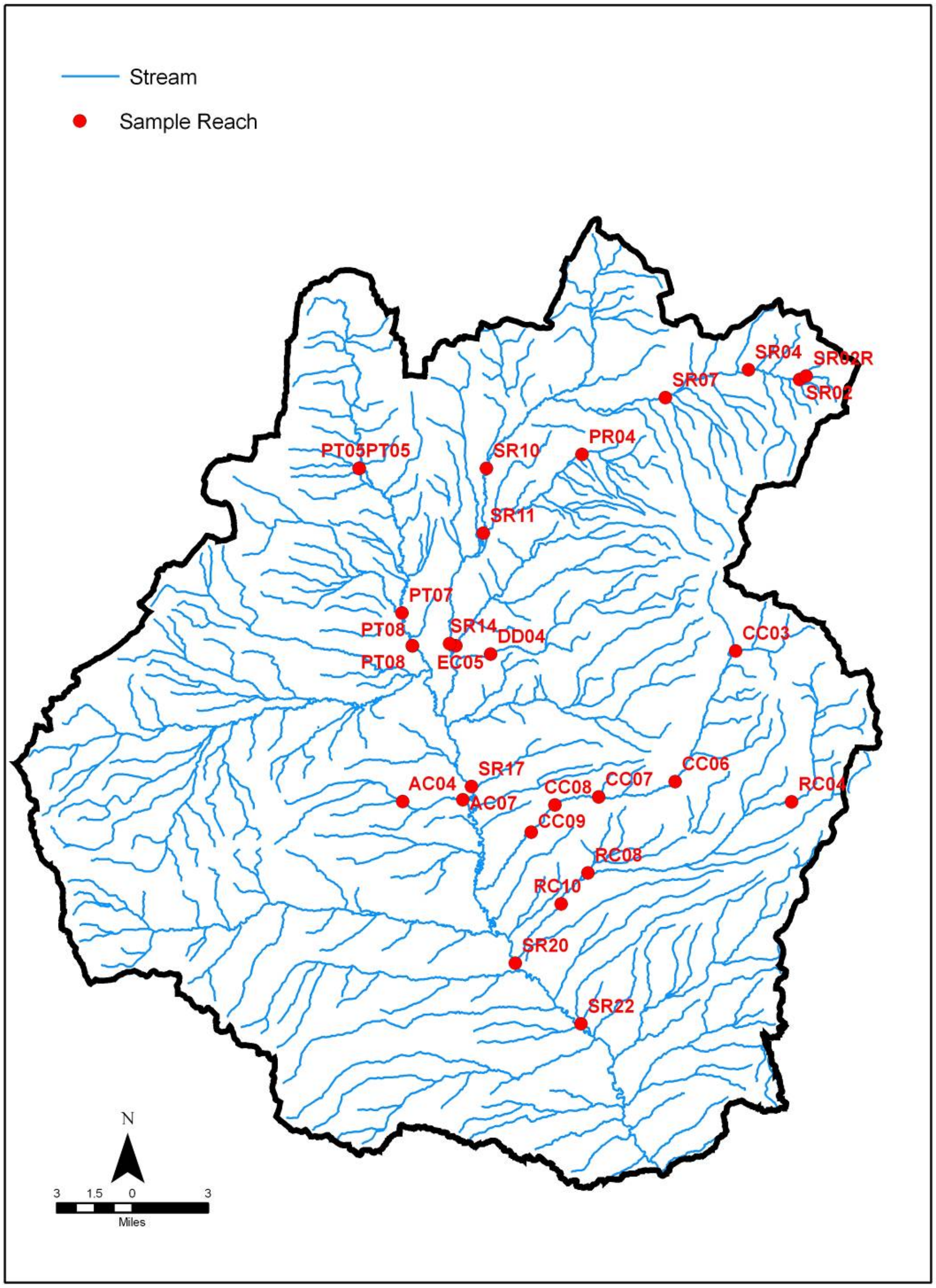

Figure F-2. Bank Erosion Assessment Sample Reach Locations

Calculation of sediment contribution from field data

Data collected in the field were used to predict the BEHI. The following data were collected for each bank.

- Bank Height, A (ft)
- Bankfull Height, B (ft)
- Root Depth, C (ft)
- Root Density, D (%)
- Bank Angle (deg.)
- Surface Protection (%)

The following erodibility variables (values) were computed and considered in ranking each bank as per Rosgen (2004).

- Bank Height / Bankfull Height, (A/B)
- Root Depth / Bank Height, (C/A)
- Weighted Root Density, (D*C/A)
- Bank Angle (deg.)
- Surface Protection (%)

The erodibility variable values were converted to numerical indices for bank erosion potential based on the relationships determined by Rosgen (2004) (**Table F-1**).

Table F-1 Conversion from Erodibility Variable Index to Numerical Bank Erosion Potential Values
(Rosgen 2004)

Erodibility Variable		Bank Erosion Potential					
		Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Bank Height / Bankfull Height	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	21. - 2.8	> 2.8
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth / Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	< 0.05
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	< 5.0
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	> 119
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	< 10
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

The BEHI method also allows the practitioner to modify the score based on bank material and bank material stratification. Rationale for exclusion of these factors from data collection and analysis related to the use of an average retreat rate assigned to each BEHI ranking. Addition of the bank material and bank material stratification to this analysis would have greatly complicated analyses without a commensurate increase in certainty in the results. Moreover, these qualitative assessments likely have low replicability. Therefore, the expense of collecting the additional data, combined with the lack of reliability in the results, justified the omission of these parameters.

A total score for each bank was developed by summing the bank erosion potential indices determined in the previous step. Finally, a BEHI ranking was assigned to the bank based on the following classification developed by Rosgen (2004).

Total Score	5 - 9.9	10 - 19.9	20 - 29.9	30 - 39.9	40 - 45	45.1 - 50
BEHI Rating	*Very Low*	*Low*	*Moderate*	*High*	*Very High*	*Extreme*

This classification was modified slightly to allow for analysis based on the Rosgen Colorado data set (**Figure F-3**). Shown here, the modification included elimination of the *Very Low* category (which was not recorded in either the Colorado data set or in the Shields Watershed sampling), and combining the *High* and *Very High* categories into one. The BEHI score and modified adjective rating for sample reaches are shown in **Table F-2**.

Total Score	10 - 19.9	20 - 29.9	30 - 45	45.1 - 50
BEHI Rating	*Low*	*Moderate*	*High - Very High*	*Extreme*

Table F-2. BEHI scores and ratings for assessment reaches

Reach	BankID	BEHI Score	Adjective Rating
AC04	AC04-1	0.0	low
AC07	AC07-1	37.0	high
PT05	PT05-1	0.0	low
PT07	PT07-1	0.0	low
PT08	PT08-1	42.9	high
PT08	PT08-2	40.9	high
PT08	PT08-3	31.4	high
PT08	PT08-4	39.2	high
PT08R	PT08R-1	32.5	high
PT08R	PT08R-2	40.1	high
PT08R	PT08R-3	42.3	high
PT08R	PT08R-4	41.4	high
SR02	SR02-1	10.5	low
SR02R	SR02R-1	29.9	high
SR02R	SR02R-2	37.2	high
SR02R	SR02R-3	40.1	high
SR02R	SR02R-4	29.1	moderate
SR02R	SR02R-5	43.8	high
SR04	SR04-1	0.0	low
SR07	SR07-1	41.9	high
SR07	SR07-2	39.3	high
SR07	SR07-3	41.0	high
SR07	SR07-4	44.3	high
SR07	SR07-5	34.4	high
SR10	SR10-1	35.7	high
SR11	SR11-1	26.2	moderate
SR14	SR14-1	41.9	high
SR14	SR14-2	38.6	high
SR14	SR14-3	35.4	high
SR14	SR14-4	26.0	moderate
SR17	SR17-1	30.8	high
SR17	SR17-2	31.3	high

Table F-2. BEHI scores and ratings for assessment reaches

Reach	BankID	BEHI Score	Adjective Rating
SR20	SR20-1	40.6	high
SR20	SR20-2	28.6	moderate
SR22	SR22-7	27.2	moderate
SR22	SR22-1	33.0	high
SR22	SR22-2	27.5	moderate
SR22	SR22-3	33.0	high
SR22	SR22-4	26.4	moderate
SR22	SR22-5	23.7	moderate
SR22	SR22-6	26.2	moderate

Near bank shear stress was estimated for each sampled eroding bank by using method 5 from Rosgen (2004). This method estimates the near bank shear stress of a bank segment from the ratio of near-bank maximum depth to bankfull mean depth according to the relationship expressed below.

Method Number	1	2	3	4	5	6	7
Rating*							
Very Low	N/A	>3.0	< 0.20	< 0.4	<1.0	<0.8	<1.0
Low		2.21 - 3.0	0.20 - 0.40	0.41 - 0.60	1.0 - 1.5	0.8 - 1.05	1.0 - 1.2
Moderate		2.01 - 2.2	0.41 - 0.60	0.61 - 0.80	1.51 - 1.8	1.06 - 1.14	1.21 - 1.6
High	See (1) Above	1.81 - 2.0	0.61 - 0.80	0.81 - 1.0	1.81 - 2.5	1.15 - 1.19	1.61 - 2.0
Very High		1.5 - 1.8	0.81 - 1.0	1.01 - 1.2	2.51 - 3.0	1.20 - 1.60	2.01 - 2.3
Extreme		< 1.5	> 1.0	> 1.2	> 3.0	> 1.6	> 2.3

***Circle the dominant near-bank stress rating selected.**

The lateral bank erosion rate was predicted using the modified BEHI rating, the estimated NBS rating, and rating curves developed by Rosgen from the Colorado dataset (**Figure F-3**).

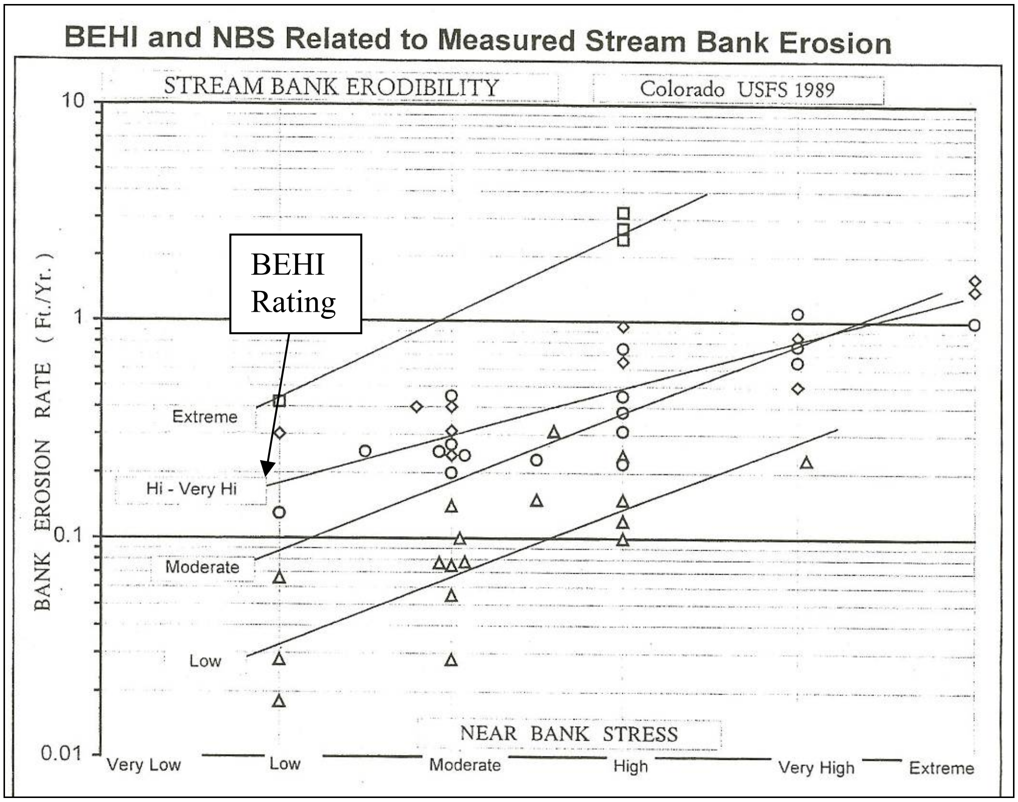

Figure F-3. Rosgen BEHI-NBS Model Developed from Colorado data
(Rosgen 2001)
Triangle (Δ) represents Low BEHI rating. Circle (○) represents Moderate BEHI rating. Diamond (◊) represents High/Very High BEHI rating. Square (□) represents Extreme BEHI rating.

Mean erosion rate values were determined for each of the combinations of BEHI and NBS ratings that appear in the sample data (**Table F-3**), and assigned to each sampled eroding bank on that basis.

Table F-3. Mean Bank Erosion Rate Based on BEHI Rating and Near Bank Shear Stress

		Near Bank Shear Stress Rating					
		Very low	Low	Moderate	High	Very high	Extreme
BEHI RATING	Extreme		0.45	1.05	2.3		
	Very high/High	*	0.18	0.29	0.5	0.8	
	Moderate	*	0.09	0.18	0.38	0.79	
	Low		0.03	0.06	0.12	0.27	

Sediment contribution from measured bank erosion sites was then estimated by applying Equation 1.

$$S = c \times R \times A \qquad (1)$$

Where: S = sediment load (ton/year)
c = bulk density of soil (0.084 ton/cubic foot)
R = bank erosion rate (feet/year)
A = eroding bank area (square feet)
And: A = eroding bank length (feet) x eroding bank height (feet)

The volume of all observed eroding banks was summed for each sampling reach, and divided by the length of the sampled stream reach, to arrive at an annual sediment contribution from that reach in tons/ft/yr.

Extrapolation
The average annual sediment contribution of the sampled stream reaches was used, in combination with data from an aerial photo based assessment of the streams of the Shields River Watershed, to create a matrix of extrapolation factors. These extrapolation factors were then multiplied by the total length of streams within each extrapolation classification, and the results broken out by 6th Code HUC boundary (modified to reflect 303d listed stream drainages) to arrive at a predicted annual sediment contribution for each watershed.

To derive and apply the extrapolation factors, an aerial photo based assessment was performed on stream channel data for the entire Shields River Watershed using the National Hydrologic Dataset (NHD), overlain on DOQQ aerial photos. Similar stream segments were stratified by the following attributes:

- current Rosgen stream channel type
- potential Rosgen stream channel type
- current near bank vegetation density
- potential near bank vegetation density
- current near bank vegetation type
- potential near bank vegetation type
- current landuse

Rosgen level 1 channel types were assigned to reaches based on the following criteria:

- B channels – low sinuosity, relatively confined, narrow floodplain, no extensive bar formation, relatively narrow channel widths.

- C channels – moderate sinuosity, gravel deposition common on point bars.

- E channels – high sinuosity, wide, unconfined floodplain, few observable gravel point bars.

- F channels – areas obviously altered by mechanical channelization. Although it is impossible to determine entrenchment ratio by aerial photos, channelized reaches are typically incised due to vertical erosion resulting from channelization and artificial berms along the channel margin placed during the channelization process.

- G channels – areas obviously altered by mechanical channelization and are much wider than adjacent reaches. These channels have begun the evolution from an F channel to a stable channel type and are widening to establish an inset floodplain.

The Rosgen classification assigned to each reach was ultimately not used in extrapolating sediment loads between sampled and non-sampled reaches.

The potential condition for Rosgen channel type, near bank vegetation density and near bank vegetation type were intended to reflect the state that could be achieved under best management practices. Possible values for the vegetation density assessments (both current and potential) were 'sparse,' 'moderate,' and 'dense.' Possible values for the vegetation type assessments (both current and potential) were 'coniferous trees,' 'deciduous trees,' 'willow shrubs,' and 'herbaceous vegetation.' Possible values for the land use assessment were 'crop,' 'forested,' 'grazing,' 'hay,' 'logging,' and 'residential.'

This same aerial assessment was performed on the stream reaches that had been field sampled for bank erosion. Deriving extrapolation factors from these sample data involved looking for relationships between combinations of aerial assessment attributes and the measured erosion rate for those combinations on the sample reaches. For example, one might examine the combination of current vegetation density and land use. Given three possible values for current vegetation density (sparse, moderate, dense) and five possible values for land use (crop, forested, grazing, hay, logging, and residential) there are fifteen possible combinations of these two attributes. One may then divide the sample reach data into those fifteen categories, calculate measured bank erosion for each category, and evaluate the results to determine if the relationship between the categories and their measured erosion rates is appropriate for use in extrapolating the sample results to the watershed as a whole.

Examination of the sample data in this manner showed the best relationship between the aerial assessment parameters and measured erosion rates involved the combination of current vegetation density, current vegetation type, and potential vegetation type. We believe this reflects the known effect of vegetation density and type on stream bank stability (e.g. dense willow stands hold banks more strongly than sparse herbaceous vegetation) as well as the effect that riparian land cover modification has on stream bank stability (e.g. streams that developed their morphology in an area of sparse herbaceous vegetation are likely to be more stable than those that developed in an area of dense woody vegetation that has since been removed).

Given that there are three possible values for current vegetation density (sparse, moderate, dense) and four possible values for both current and potential vegetation type (coniferous, deciduous, willow, herbaceous), there are 48 possible combinations of those three attributes. Some of those combinations do not 'make sense' and do not actually occur, however. For example, a stream segment should not have a current vegetation type of 'willow' and a potential vegetation type of

'herbaceous' as that does not reflect the expected result of best management practices. This reduces the number of possible combinations to 30, still too many for a meaningful extrapolation based upon 52 sample reaches – most of the possible combinations would have too few (or no) corresponding samples. A further reduction in possible combinations can be achieved by considering that, with respect to current and potential vegetation type, what is important from the standpoint of streambank erosion is whether or not the site is achieving its potential vegetation type. For example, sites that currently have herbaceous vegetation might have the potential to have herbaceous, willow, deciduous, or coniferous vegetation – four potential categories. These four categories can be reduced to two by considering a herbaceous site to be 'achieving its potential' if its potential is to support herbaceous vegetation and 'not achieving' if it has the potential to support any of the other three higher seral stages.

Reclassifying the vegetation type combinations according to 'achieving' or 'underachieving' results in 24 combinations. The number of samples corresponding to each of these 24 combinations is shown in **Figure F-4**.

Vegtype & Vegtype Potential & VegDensity

Sparse Veg	Herbaceous	Willow	Deciduous	Coniferous
Achieving		1		
Underachieving	1			

Moderate Veg	Herbaceous	Willow	Deciduous	Coniferous
Achieving	3	1	2	3
Underachieving	2			

Dense Veg	Herbaceous	Willow	Deciduous	Coniferous
Achieving		1	7	3
Underachieving				

Figure F-4. Extrapolation Matrix Showing the Distribution of Vegetation Type, Density, and Potential for Sample Sites

Of the 24 possible combinations, only ten are represented in the sample data. However, not all of the combinations are found in the watershed, and thus in need of an extrapolation factor. In **Figure F-4**, green cells represent combinations for which samples exist. Grey cells represent combinations which do not appear in the data for the watershed as a whole. Red cells represent combinations which do appear in the data for the watershed as a whole, but for which there are no samples. Thus, the sample data cover ten of the fourteen combinations found in the watershed as a whole. To judge whether or not this coverage is sufficient to develop a meaningful extrapolation, we looked at the proportion of the watershed as a whole that were covered by the sampled combinations.

Vegtype & Vegtype Potential & VegDensity

	Herbaceous	Willow	Deciduous	Coniferous
Sparse Veg				
Achieving	374,478	78,277	11,555	8,183
Underachieving	163,691			
Moderate Veg				
Achieving	115,040	370,583	208,853	300,440
Underachieving	47,965			
Dense Veg				
Achieving	10,899	95,569	4,645	111,725
Underachieving				

Figure F-5. Extrapolation Matrix Showing the Length of Stream Channel for each Vegetation Type, Density, and Potential for the Shields Watershed

As shown in **Figure F-5**, approximately 80% of the stream segments (by length) in the valley were represented by the sampled categories, and more than 90% of the remainder were in a single category (sparse, herbaceous, achieving) for which an appropriate factor could be easily derived from the sample data. Therefore, the sampled sites provide an adequate representation of conditions within the Shields Watershed. The average erosion rate (tons/ft/yr) was calculated for all of the combinations that had been sampled (**Figure F-6**).

Vegtype & Vegtype Potential & VegDensity

	Herbaceous	Willow	Deciduous	Coniferous
Sparse Veg				
Achieving		0.001	*	*
Underachieving	0.045			
Moderate Veg				
Achieving	0.000	0.022	0.019	0.013
Underachieving	0.017			
Dense Veg				
Achieving	*	0.002	0.010	0.013
Underachieving				

Figure F-6. Extrapolation Matrix – The Average Erosion Rate Tons/ft/yr) for each Site Type Sampled
Asterisks denote categories with minimal representation in the watershed.

From this starting point, a final extrapolation factor matrix was derived using best professional judgment, as follows:

- Herbaceous
  In all cases, reaches exhibiting an "achieving" potential were assigned a lower loading rate than those exhibiting an "underachieving" potential. Likewise, reaches exhibiting dense vegetation were assigned a lower erosion rate than moderate and sparse densities. All herbaceous categories were assigned higher sediment loads than the corresponding density and potential for willow stands (i.e. a moderate density, herbaceous reach achieving its vegetation potential was assigned a higher sediment load than a moderate density, willow dominated reach achieving its vegetation potential) because herbaceous stands typically exhibit higher erosion rates than willow stands.

- Willow
  All three willow vegetation density categories were field measured and assigned an "achieving" potential. However, the sediment load measured for the moderate category of willows indicated a higher sediment load than the sparse density category. Best professional judgment was used to infer that a moderate stand of willows should exhibit a lower sediment load than a sparse stand. Therefore, the moderate and sparse, achieving reaches were reassigned a sediment load rate to reflect lower loads than the dense, achieving reaches. These dense, achieving reaches remained at the measured sediment load of 0.002 tons/ft/year.

- Deciduous
  A similar judgment was used for deciduous stands as was used for willow stands. Best professional judgment was used to infer that a dense stand of deciduous trees would exhibit a lower sediment loading rate than moderate and sparse stands due to the increased amount of root binding mass. Best professional judgment was also used to infer that a dense stand of deciduous vegetation likely exhibits a moderate, herbaceous understory. Therefore, the assigned sediment load rate (0.02 tons/ft/yr) was chosen to closely match the moderate density, achieving potential, herbaceous reaches (0.01 tons/ft/yr). Although deciduous roots provide some bank stability due to their massive root systems, they are typically not as effective as the fibrous network of shrub and herbaceous roots. Therefore a slightly higher loading rate was assigned to the dense, deciduous-dominated stand versus the moderate, herbaceous stand.

- Coniferous
  Reaches in the Shields Watershed exhibiting a coniferous-dominated vegetation type are located in upper elevation areas exhibiting typically steeper channels (A and B types). These steeper streams typically exhibit cobble and boulder bed morphology which generally provide excellent bank stability in the form of narrow, step pools and steep riffles. Erosion rates in these streams are typically very low due to the bed material preventing vertical and lateral scouring. Some coniferous reaches were also found in the transition between B and lower gradient C channels at mid-elevations within the watershed.

  Reaches CC06 and SR02R were removed from the data set due to cases of extremely high eroding bank heights >50 feet. The high bank heights in these reaches caused the average sediment loads for this vegetation category to more than double. Although these

bank heights were accurately measured, the entire bank is not actively eroding. Sample reaches included both moderate and dense, achieving coniferous stands, each resulting in a sediment load of 0.013 tons/ft/year. These values were assigned slightly different values (0.015 and 0.010 tons/ft/year respectively) based on the judgment that coniferous stands are more stable due to the majority of the reaches falling in the steeper, cobble and boulder bed morphology areas of the drainage. A sparse, coniferous stand is likely to have a sparse to moderate herbaceous understory. Therefore a load rate was assigned to this category that represented a close value to both of these individual vegetation types (0.02 tons/ft/year). Each sampled site type was assigned an average annual loading rate that was used to extrapolate to the rest of the Shields Watershed (**Figure F-7**).

	Vegtype & Vegtype Potential & VegDensity			
		Sparse Veg		
	Herbaceous	Willow	Deciduous	Coniferous
Achieving	0.02	0.005	0.04	0.02
Underachieving	0.04			
		Moderate Veg		
	Herbaceous	Willow	Deciduous	Coniferous
Achieving	0.01	0.004	0.03	0.015
Underachieving	0.03			
		Dense Veg		
	Herbaceous	Willow	Deciduous	Coniferous
Achieving	0.005	0.002	0.02	0.01
Underachieving				

Figure F-7. Extrapolation Matrix of the Average Loading Rate (tons/ft/yr) for each Site Type

These factors were applied to all of the stream channel segments for the Shields River Watershed, total sediment load from existing conditions calculated, and the results summarized by sub-watershed.

To estimate the sediment produced under best management practices, each stream segment in the watershed was assigned an extrapolation factor based upon that segment's potential vegetation type and density, total sediment load from BMP conditions calculated, and the results summarized by sub-watershed.

Example: A stream segment was classified by the aerial assessment as currently having moderate, herbaceous vegetation cover. This stream segment was also classified as having the potential to support dense willow cover. This stream segment would be assigned the extrapolation factor for moderate, herbaceous, underachieving (0.03 tons/ft/yr) to reflect its sediment delivery under existing conditions, and the factor for dense, willow, achieving (0.01) to reflect its potential sediment delivery under BMP.

Results

Table F-4 presents the bank erosion loads by 6th code HUC sub-watershed and the subwatershed loads normalized by the total stream length in each subwatershed. **Table F-5** presents the results reported by surface land ownership classification.

Table F-4. Bank Erosion Extrapolation Results by Subwatershed and for the Shields Watershed

6th Code HUC Subwatershed	Length of Streams in Watershed (ft)	Current Sediment Delivery (tons/yr)	Potential Sediment Delivery (tons/yr)	Normalized Current Sediment Delivery (tons/ft/yr)	Normalized Potential Sediment Delivery (tons/ft/yr)
Adair Creek	169,371	2,200	1,500	0.013	0.009
Bangtail Creek	68,543	300	200	0.004	0.003
Canyon Creek	158,433	1,400	1,100	0.009	0.007
Carrol Creek	227,679	3,600	1,600	0.016	0.007
Cottonwood Creek East	246,028	4,500	4,400	0.018	0.018
Cottonwood Creek West	209,313	2,700	1,100	0.013	0.005
Daisy Dean Creek	125,185	1,700	1,100	0.013	0.009
Dry Creek	169,360	3,300	1,600	0.019	0.009
Elk Creek	214,678	3,200	1,300	0.015	0.006
Falls Creek	208,293	3,500	1,500	0.017	0.007
Horse Creek	267,955	4,600	2,900	0.017	0.011
Lower Brackett Creek	124,502	2,200	1,300	0.017	0.010
Lower Flathead Creek	259,458	3,500	1,500	0.014	0.006
Lower Shields River-Chicken Creek	284,351	7,200	4,300	0.025	0.015
Lower Shields River-Crazyhead Creek	223,344	4,500	3,000	0.020	0.014
Meadows Creek	171,265	1,900	1,500	0.011	0.009
Middle Shields River-Antelope Creek	395,833	6,000	4,200	0.015	0.011
Middle Shields River-Spring Creek	112,055	3,200	2,000	0.028	0.018
Muddy Creek	168,914	2,300	1,100	0.013	0.006
Porquepine Creek	264,224	4,600	2,000	0.017	0.008
Potter Creek	**468,499**	**8,100**	**4,700**	**0.017**	**0.010**
Rock Creek	373,868	8,300	5,500	0.022	0.015
Upper Brackett Creek	260,278	2,900	2,100	0.011	0.008
Upper Flathead Creek	142,866	2,100	800	0.015	0.006
Upper Shields River-Antelope Creek	166,649	2,800	2,100	0.017	0.012
Upper Shields River-Bennett Creek	387,189	6,500	4,700	0.017	0.012
Upper Shields River-Kavanaugh Creek	189,374	4,800	3,000	0.025	0.016
Willow Creek	182,330	1,100	800	0.006	0.004
Shields Watershed	**6,239,838**	**103,000**	**62,900**	**0.016**	**0.010**

Table F-5. Bank Erosion Extrapolation Results by Land Ownership

Ownership Classification	Length of Streams by ownership (ft)	Estimated Current Sediment Delivery (tons/yr)	Estimated Potential Sediment Delivery (tons/yr)
Private	5,201,203	88,050	51,060
Right of Way	6,434	140	120
State Government	146,287	2,450	1,290
Undetermined	40	<10	<10
US Government	50,162	1,000	570
USDA Forest Service	833,880	11,200	9,720
USDI Bureau of Land Management	1,833	20	20
Grand Total	**6,239,838**	**103,000**	**62,900**

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APPENDIX G
TOTAL MAXIMUM DAILY LOADS

Approach

The average annual sediment loads determined from source assessments (**Section 5.0**) were used along with historical flow and suspended sediment data from the Shields River to determine average daily sediment loads for the Shields River and Potter Creek. A sediment rating curve was developed using flow and suspended solids data collected from 1999 through 2003 at the USGS gage at Livingston (Station 6195600) (**Figure G-1**).

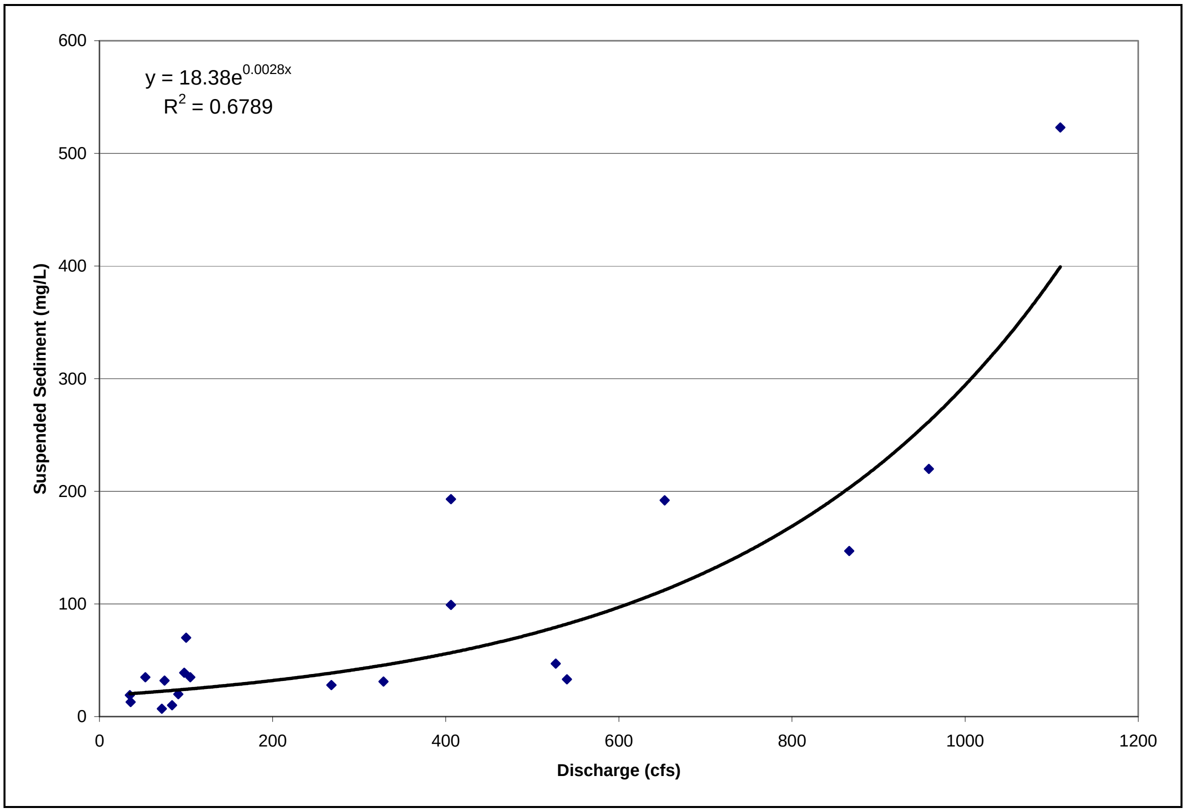

Figure G-1. Sediment Rating Curve for the Shields River

The daily mean discharge based on 28 years of record (1978-2006) at the USGS gage was then plugged into the equation for the sediment rating curve to get a daily suspended sediment value. The suspended sediment value is only a fraction of the total load from the source assessment, but provides an approximation of the relationship between sediment and flow in the Shields River. Based on the sum of the calculated daily sediment values, a daily percentage relative to the annual suspended sediment load was calculated for each day. The daily percentages were then applied to the total average annual loads associated with the TMDL percent reductions from **Section 7.0** for the Shields River and Potter Creek (151,000 and 8,500 tons/year, respectively) to determine the average daily load (**Figure G-2 and G-3, Table G-1**). Although the relationship between sediment in flow is likely different in Potter Creek than in the Shields River, it was used to determine average daily loads because it is the best available data and TMDL implementation

activities will not be driven by the daily loads. The daily loads are a composite of the allocations. Daily allocations for roads, upland erosion, and streambank erosion can be calculated for a particular day by multiplying the values in **Table G-2** by that day's average load. For example, the Shields River average daily load for January 1 is 36 tons and the allocations are as follows:

- Upland Erosion – 15 tons
- Streambank Erosion – 21 tons
- Unpaved Roads – < 1 ton

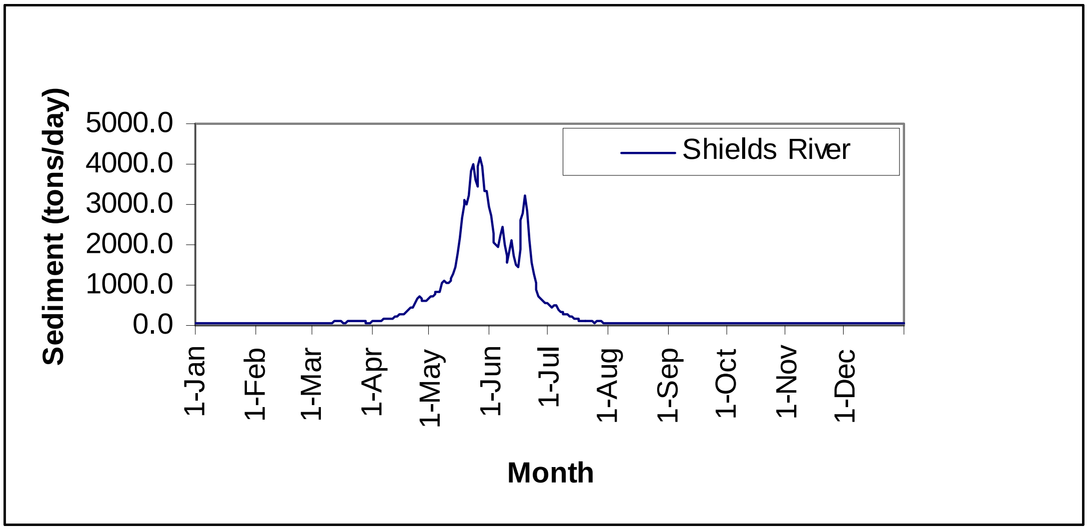

Figure G-2. Average Daily Sediment Load for the Shields River

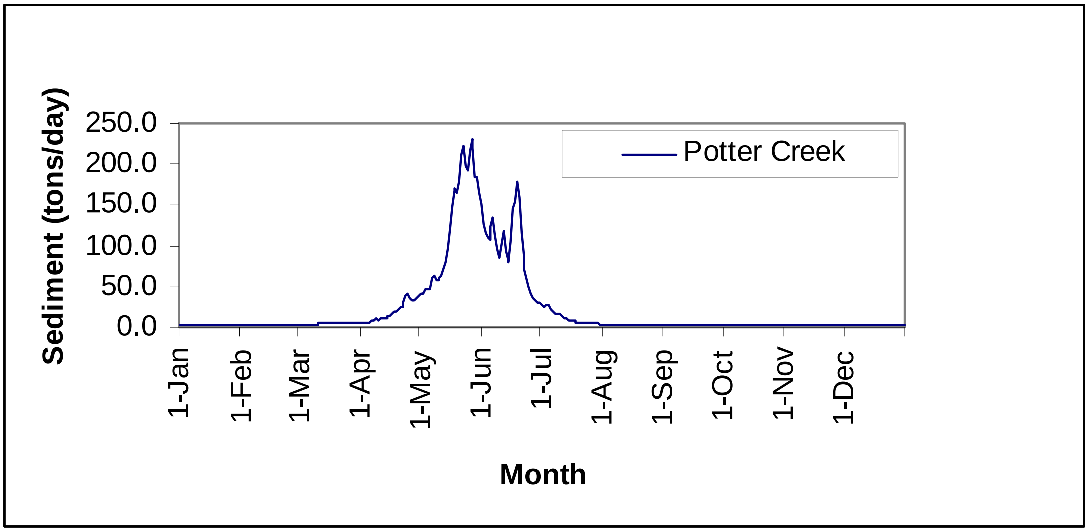

Figure G-3. Average Daily Sediment Load for Potter Creek

Table G-1. Daily TMDL for the Shields River and Potter Creek.

Month	Day	Shields TMDL (tons/day)	Potter Creek TMDL (tons/day)	Month	Day	Shields TMDL (tons/day)	Potter Creek TMDL (tons/day)
Jan	1	36	2	Feb	16	40	2
Jan	2	37	2	Feb	17	48	3
Jan	3	38	2	Feb	18	47	3
Jan	4	37	2	Feb	19	46	3
Jan	5	37	2	Feb	20	54	3
Jan	6	43	2	Feb	21	60	3
Jan	7	46	3	Feb	22	57	3
Jan	8	43	2	Feb	23	42	2
Jan	9	39	2	Feb	24	40	2
Jan	10	38	2	Feb	25	46	3
Jan	11	37	2	Feb	26	55	3
Jan	12	36	2	Feb	27	50	3
Jan	13	36	2	Feb	28	44	2
Jan	14	36	2	Feb	29	38	2
Jan	15	36	2	Mar	1	44	2
Jan	16	36	2	Mar	2	46	3
Jan	17	35	2	Mar	3	46	3
Jan	18	36	2	Mar	4	46	3
Jan	19	35	2	Mar	5	43	2
Jan	20	36	2	Mar	6	45	2
Jan	21	35	2	Mar	7	49	3
Jan	22	35	2	Mar	8	54	3
Jan	23	35	2	Mar	9	60	3
Jan	24	35	2	Mar	10	62	3
Jan	25	34	2	Mar	11	79	4
Jan	26	35	2	Mar	12	97	5
Jan	27	35	2	Mar	13	115	6
Jan	28	37	2	Mar	14	107	6
Jan	29	35	2	Mar	15	106	6
Jan	30	34	2	Mar	16	94	5
Jan	31	35	2	Mar	17	82	5
Feb	1	51	3	Mar	18	77	4
Feb	2	52	3	Mar	19	99	5
Feb	3	37	2	Mar	20	117	6
Feb	4	35	2	Mar	21	120	7
Feb	5	34	2	Mar	22	100	6
Feb	6	35	2	Mar	23	95	5
Feb	7	49	3	Mar	24	95	5
Feb	8	63	3	Mar	25	89	5
Feb	9	59	3	Mar	26	86	5
Feb	10	51	3	Mar	27	95	5
Feb	11	36	2	Mar	28	85	5
Feb	12	36	2	Mar	29	82	5
Feb	13	36	2	Mar	30	82	5
Feb	14	39	2	Mar	31	82	5
Feb	15	39	2	Apr	1	85	5
				Apr	2	104	6

Table G-1. Daily TMDL for the Shields River and Potter Creek.

Month	Day	Shields TMDL (tons/day)	Potter Creek TMDL (tons/day)	Month	Day	Shields TMDL (tons/day)	Potter Creek TMDL (tons/day)
Apr	3	112	6	May	20	2990	166
Apr	4	107	6	May	21	3246	180
Apr	5	100	6	May	22	3834	212
Apr	6	119	7	May	23	4015	222
Apr	7	153	8	May	24	3591	199
Apr	8	169	9	May	25	3468	192
Apr	9	176	10	May	26	3939	218
Apr	10	170	9	May	27	4156	230
Apr	11	177	10	May	28	3954	219
Apr	12	186	10	May	29	3310	183
Apr	13	199	11	May	30	3336	185
Apr	14	220	12	May	31	2967	164
Apr	15	251	14	Jun	1	2710	150
Apr	16	265	15	Jun	2	2302	128
Apr	17	297	16	Jun	3	2065	114
Apr	18	333	18	Jun	4	1974	109
Apr	19	366	20	Jun	5	1927	107
Apr	20	399	22	Jun	6	2238	124
Apr	21	444	25	Jun	7	2444	135
Apr	22	467	26	Jun	8	2023	112
Apr	23	554	31	Jun	9	1725	96
Apr	24	685	38	Jun	10	1542	85
Apr	25	724	40	Jun	11	1857	103
Apr	26	651	36	Jun	12	2124	118
Apr	27	601	33	Jun	13	1696	94
Apr	28	607	34	Jun	14	1473	82
Apr	29	624	35	Jun	15	1442	80
Apr	30	673	37	Jun	16	1872	104
May	1	724	40	Jun	17	2605	144
May	2	741	41	Jun	18	2797	155
May	3	762	42	Jun	19	3234	179
May	4	823	46	Jun	20	2853	158
May	5	827	46	Jun	21	2107	117
May	6	857	47	Jun	22	1568	87
May	7	1083	60	Jun	23	1297	72
May	8	1121	62	Jun	24	1083	60
May	9	1064	59	Jun	25	868	48
May	10	1055	58	Jun	26	734	41
May	11	1102	61	Jun	27	660	37
May	12	1146	63	Jun	28	618	34
May	13	1292	72	Jun	29	570	32
May	14	1436	80	Jun	30	530	29
May	15	1753	97	Jul	1	483	27
May	16	2185	121	Jul	2	476	26
May	17	2678	148	Jul	3	458	25
May	18	3014	167	Jul	4	510	28
May	19	3086	171	Jul	5	495	27
				Jul	6	416	23

Table G-1. Daily TMDL for the Shields River and Potter Creek.

Month	Day	Shields TMDL (tons/day)	Potter Creek TMDL (tons/day)	Month	Day	Shields TMDL (tons/day)	Potter Creek TMDL (tons/day)
Jul	7	358	20	Aug	24	48	3
Jul	8	317	18	Aug	25	49	3
Jul	9	284	16	Aug	26	49	3
Jul	10	289	16	Aug	27	48	3
Jul	11	283	16	Aug	28	47	3
Jul	12	244	14	Aug	29	47	3
Jul	13	220	12	Aug	30	47	3
Jul	14	193	11	Aug	31	46	3
Jul	15	168	9	Sep	1	45	3
Jul	16	154	9	Sep	2	45	2
Jul	17	138	8	Sep	3	44	2
Jul	18	129	7	Sep	4	43	2
Jul	19	121	7	Sep	5	43	2
Jul	20	112	6	Sep	6	44	2
Jul	21	109	6	Sep	7	43	2
Jul	22	97	5	Sep	8	43	2
Jul	23	91	5	Sep	9	44	2
Jul	24	84	5	Sep	10	43	2
Jul	25	79	4	Sep	11	44	2
Jul	26	88	5	Sep	12	50	3
Jul	27	105	6	Sep	13	54	3
Jul	28	94	5	Sep	14	52	3
Jul	29	82	5	Sep	15	50	3
Jul	30	76	4	Sep	16	48	3
Jul	31	69	4	Sep	17	47	3
Aug	1	64	4	Sep	18	47	3
Aug	2	59	3	Sep	19	49	3
Aug	3	56	3	Sep	20	51	3
Aug	4	53	3	Sep	21	52	3
Aug	5	52	3	Sep	22	53	3
Aug	6	52	3	Sep	23	53	3
Aug	7	46	3	Sep	24	52	3
Aug	8	45	3	Sep	25	52	3
Aug	9	45	3	Sep	26	51	3
Aug	10	44	2	Sep	27	52	3
Aug	11	43	2	Sep	28	55	3
Aug	12	44	2	Sep	29	53	3
Aug	13	44	2	Sep	30	52	3
Aug	14	44	2	Oct	1	59	3
Aug	15	43	2	Oct	2	59	3
Aug	16	43	2	Oct	3	59	3
Aug	17	44	2	Oct	4	61	3
Aug	18	42	2	Oct	5	64	4
Aug	19	43	2	Oct	6	61	3
Aug	20	42	2	Oct	7	59	3
Aug	21	42	2	Oct	8	59	3
Aug	22	52	3	Oct	9	59	3
Aug	23	53	3	Oct	10	58	3

Table G-1. Daily TMDL for the Shields River and Potter Creek.

Month	Day	Shields TMDL (tons/day)	Potter Creek TMDL (tons/day)	Month	Day	Shields TMDL (tons/day)	Potter Creek TMDL (tons/day)
Oct	11	59	3	Nov	26	46	3
Oct	12	59	3	Nov	27	45	3
Oct	13	59	3	Nov	28	45	3
Oct	14	59	3	Nov	29	44	2
Oct	15	61	3	Nov	30	44	2
Oct	16	62	3	Dec	1	44	2
Oct	17	62	3	Dec	2	45	3
Oct	18	61	3	Dec	3	46	3
Oct	19	61	3	Dec	4	46	3
Oct	20	61	3	Dec	5	44	2
Oct	21	59	3	Dec	6	44	2
Oct	22	59	3	Dec	7	42	2
Oct	23	59	3	Dec	8	42	2
Oct	24	59	3	Dec	9	44	2
Oct	25	59	3	Dec	10	44	2
Oct	26	59	3	Dec	11	41	2
Oct	27	58	3	Dec	12	41	2
Oct	28	58	3	Dec	13	43	2
Oct	29	58	3	Dec	14	43	2
Oct	30	57	3	Dec	15	41	2
Oct	31	57	3	Dec	16	39	2
Nov	1	55	3	Dec	17	37	2
Nov	2	56	3	Dec	18	36	2
Nov	3	56	3	Dec	19	35	2
Nov	4	56	3	Dec	20	35	2
Nov	5	57	3	Dec	21	36	2
Nov	6	57	3	Dec	22	35	2
Nov	7	56	3	Dec	23	34	2
Nov	8	55	3	Dec	24	34	2
Nov	9	56	3	Dec	25	36	2
Nov	10	55	3	Dec	26	38	2
Nov	11	52	3	Dec	27	37	2
Nov	12	52	3	Dec	28	35	2
Nov	13	54	3	Dec	29	34	2
Nov	14	55	3	Dec	30	36	2
Nov	15	52	3	Dec	31	36	2
Nov	16	54	3				
Nov	17	53	3				
Nov	18	53	3				
Nov	19	53	3				
Nov	20	51	3				
Nov	21	49	3				
Nov	22	48	3				
Nov	23	45	2				
Nov	24	46	3				
Nov	25	47	3				

Table G-2. Daily Allocation Factors for Upland Erosion, Bank Erosion, and Unpaved Roads

They can be multiplied by the average daily loads to get a daily allocation		
Source	**Shields River**	**Potter Creek**
Upland Erosion	0.413	0.556
Streambank Erosion	0.586	0.443
Unpaved Roads	0.001	0.001

APPENDIX H
SHIELDS VALLEY WATERSHED GROUP RESTORATION PRIORITIES

The priorities listed within this Appendix are part of the 2008 Shields Valley Watershed Group Work Plan. It contains numerous objectives and tasks that pertain to four overarching goals related to the management of noxious weeds, agricultural land, water resources/irrigation, and wildlife. Restoration priorities directly related to water quality and quantity are not project-specific, but can be used by stakeholders in conjunction with other recommendations from this document to guide prioritization of time and resources for TMDL implementation.

GOAL 1: **Pests**: Reduce the spread of small and large infestations using an integrated management approach.

Objective A: Control the spread of noxious and invasive weeds of special concern:

Spotted Knapweed
Diffused Knapweed
Leafy Spurge
Burdock
Mullein
Musk Thistle
Dalmatian Toadflax
Yellow Toadflax
Sulphur Cinquefoil
Houndstongue
Saltcedar
Purple Loosestrife
Perennial Pepperweed
Oxeye Daisy
Field Bindweed
Dyers Woad
Common Tansy
Common St. Johnswort
Canada Thistle

Action Item 1:
- The Shields Valley Watershed Group will actively support weed control efforts including coordinating herbicide applicator training, delineating priority weed control areas, and organizing integrated pest management (IPM) projects throughout the Shields Valley.
  - Actively address these items through the 2008 Weed Fair.

Timeline: Ongoing & March 2008

Action Item 2:
- Conduct goat/sheep grazing seminars and provide information.
  - Continue to advertise the availability of the electric sheep fence to target grazing noxious weed infestations on small parcels.
  - Make noxious weed grazing information available at meetings and at the Park CD office.

Timeline: Ongoing & March 2008

Action Item 3:
- Promote biological control of noxious weeds.
  - Educate landowners of biological control methods available to them.

    - Provide bug nets for landowners to borrow and supply a bug sorter for bug collectors to use.

Timeline: Ongoing & March 2008

Objective B: Increase public awareness on the economic and environmental damage caused by the spread of noxious weeds.

Action Item 1:

- Sponsor the Annual Weed Fair/BBQ
    - Agenda Includes: Weed ID, Herbicide Product Selection, grazing management, obtaining a chemical license.

Timeline: March 2008

Action Item 2:

- The Shields Valley Watershed Group will participate in the development of the Park County Cooperative Weed Management Area. This is an intergraded effort from all surrounding federal, state, and private agencies along with the help of landowners in both watershed groups.
    - At lease one representative from the watershed will attend the CWMA meetings and then update the group at the monthly meetings.
    - The coordinator will provide necessary information in order to keep this weed effort ongoing.

Timeline: Ongoing

Action Item 3:

- Combining the locations of weed infestations onto maps of the Park County Cooperative Weed Management Area.
    - Make large maps of the Shields Valley Watershed with ArcView and the help of the Livingston Forest Service.
    - Illustrate and monitor where noxious weeds are on the large maps of the Shields Valley.

Timeline: Ongoing

Action Item 4:

- Disseminate weed control brochures and calendars at local watershed meetings and through the Park CD to encourage small acreage landowners to help in the War on Weeds targeting new and existing subdivisions.

Timeline: Ongoing

Action Item 5:

- Make personal contacts to encourage landowners to participate in educational activities and weed control projects through workshops, public outreach and media.
    - Sponsor a free GIS/GPS training workshop with the purpose of mapping the weeds on landowner's property.

- Insure that all landowners are aware of the two trailer mounted weed sprayers located within the district.

Timeline: Ongoing & summer 2008

<u>Objective C:</u> Increase public awareness on the economic and environmental damage caused by the crop consuming insects and rodents.

<u>Action Item 1:</u>

- Schedule a pest education speaker for the watershed meeting or mentoring to inform landowners about the different ways to control pests.

Timeline: Summer 2008

<u>GOAL 2</u>: Rangeland, Cropland and Pasture. Promote sound range, crop and pasture management and develop appropriate management goals and practices.

<u>Objective A:</u> Conduct range, crop and pasture education and outreach to members within the watershed group.

<u>Action Item 1:</u>

- Educate about proper rangeland monitoring, best management practices and how to become better stewards of the land.

Timeline: Spring 2009

<u>Action Item 2:</u>

- Educate and conduct an outreach to landowners through watershed speakers about animal nutrition and health management for animals that live off rangeland and pastures.

Timeline: Fall 2008

<u>Action Item 3:</u>

- Educate the landowners about fire ecology and its benefits and also ways to prevent forest fires.

Timeline: Summer 2008

<u>Action Item 4:</u>

- Conduct ranch tours as an education outreach to landowners so they can observe other landowners technology and management practices.

Timeline: Fall 2008

<u>Objective B:</u> Increase landowners' involvement with programs that help improve their land's natural resources to sustain future generations for production, recreation, and wildlife habitat.

Action Item 1:

- Promote the use of programs that help landowners increase good management goals, planning, and monitoring skills through watershed speakers and workshops.

Timeline: Ongoing

Action Item 2:

- Educate landowners about programs that will help increase their productivity through new or improved operations. Such as, Land EKG, sustainable agriculture, niche markets and alternative energy.

Timeline: Winter 2008

Action Item 3:

- Keep the watershed landowners updated with new and improved ways to live off their land.
  - Continue to offer informational pamphlets and brochures on new and improved programs/operations.

Timeline: Ongoing

GOAL 3: **Water/Irrigation:** Encourage private landowners to make decisions based on maintaining the economic value and ecological vitality of water sources in the Shields Valley.

Objective A: Maintain and/or expand existing populations of Yellowstone Cutthroat Trout and other significant fish species in the Upper Shields River Watershed.

Action Item 1:

- Continue to monitor trends of the Yellowstone Cutthroat Trout populations throughout the watershed.
  - Montana FWP will provide an extensive update at least once each year and cutthroat updates when available. Last detailed update: January 3, 2008.

Timeline: Ongoing & August 2008

Action Item 2:

- Identify and prioritize stream reaches in the watershed for fish habitat and spawning improvement projects in both the Shields River main stem and tributaries.

Timeline: Ongoing

Action Item 3:

- Fish Entrainment Prevention Projects.
  - Continue to sponsor and help identify Fish Wildlife and Parks future fish entrainment prevention projects within watershed membership group with the help of the Park Conservation District

    - Promote fish friendly structures such as fish ladders, and find funding for those willing to install them.

Timeline: Ongoing

Objective B: Improve the health and condition of the stream corridor along the Shields River mainstem and its major tributaries. Direct benefits include increased forage production, improved fishery and wildlife habitat, reduction in the loss of land through bank erosion, wetland enhancement and improved water quality, and higher property values.

Action Item 1:

- Promote necessary bank stabilization projects that will meet landowner objectives while not significantly affecting natural stream dynamics, both on-site and cumulatively.

Timeline: Ongoing

Action Item 2:

- Promote the use of concrete blocks for irrigation diversions.
    - Work with NRCS, Park Conservation District, and other agencies to implement the use of these blocks.

Timeline: Ongoing

Action Item 3:

- The SVWG will continue to evaluate the state of the watershed; identifying areas in need of riparian and/or restoration activities; establishing best methods for improving the identified areas; prioritizing the areas for riparian and/or restoration activities.

Timeline: Ongoing

Action Item 4:

- Continuation of Seal-It project (2004 MACD – LEP funded project). This product will be advertised through the watersheds and Park CD and available for 2008-2009 projects until the entire product is gone.

Timeline: Spring/Summer 2008

Objective C: Manage stream flows within the watershed to maximize benefits for the fish, wildlife, and agricultural users.

Action Item 1:

- Promote the efficient use of irrigation water using pivots, water meters, and water-saving techniques.

Timeline: Ongoing

Action Item 2:
- Support the monitoring of stream flows and irrigation withdrawals at locations of concern that support Yellowstone cutthroat trout and development of conservation and better management practices.

Timeline: Ongoing

Action Item 3:
- Increase efficiency and lower costs of energy by promoting and educating landowners about alternative energy using micro hydroelectric plants on their operation with the help of the Park CD and Josh Kellar with RC&D.

Timeline: Summer 2008

Objective C: Improve water quality throughout the Shields Watershed.

Action Item 1:
- Update the SVWG on all incoming information from the DEQ and consulting firms about the TMDL process.

Timeline: Ongoing

Action Item 2:
- Provide local coordination of public outreach activities for completion of the Shields Planning Area sediment TMDL.
  - Plan and organize meetings for presentation of the final TMDL document to the public and stakeholders for public review.
  - Distribute the final document to interested parties.
  - Help create and maintain contact with the Technical Advisory Committee.

Timeline: Ongoing

Action Item 3:
- Actively participate in the development of the Water Quality Restoration Plan/TMDL for the impaired stream reaches in the Shields Valley Watershed.

Timeline: Ongoing

Action Item 4:
- The SVWG will continue to evaluate and identify areas in need of riparian and/or restoration activities; establishing best methods for improving the identified areas; prioritizing the areas for riparian and/or restoration activities through the use of the TMDL document and help from the Park CD.

Timeline: Ongoing

Action Item 5:
- Host informational meetings/workshops for landowners in the watershed on non-point water quality issues and laws that pertain to riparian management, concentrated livestock areas, and rural subdivision impacts.

Timeline: Ongoing

Action Item 6:
- Promote best management practices through education, outreach, and restoration projects.

Timeline: Ongoing

GOAL 4: **Wildlife**. Maintain reasonable numbers of wildlife, (game birds, game animals, and native species) without negative impact on the health of the land and livestock.

Objective A: Maintain and educate wildlife management practices while collaborating with the state of Montana.

Action Item 1:
- Educate and support the landowners with the troubles of surrounding wildlife that cause damage to their production.
    - The SVWG will continue to educate landowners in the watershed area about deer/elk populations and hunting permits.

Timeline: Winter 2008

Action Item 2:
- Educate landowners about current laws and regulations in regards to wildlife and private/public property.
    - The SVWG will continue to educate landowners in the watershed area about deer/elk populations and hunting permits.

Timeline: Winter 2008

APPENDIX I
SEDIMENT & HABITAT ASSESSMENT METHODS AND DATA

This section provides a brief description of field methods used to collect morphological, habitat, and in-stream sediment data. The primary objectives of the data collection were to verify the sediment impairment status for the 303(d) Listed water bodies within the Shields TPA and gather data to evaluate conditions within the watershed relative to sediment targets that can continue to be monitored after TMDL implementation. Because of the amount of data collected, data tables included in this appendix are limited to parameters used for TMDL development. Data collected for other parameters are available by request from DEQ.

I.1 Sampling Reach Selection

Sediment and habitat sampling occurred within representative stream reaches based on the results of an aerial assessment (**Appendix A, Map A-14**).

I.2 Monitoring Base Parameters

The base parameters for sediment and habitat are a suite of measures of the stream morphology, riparian structural composition, substrate composition, and habitat that are described in the sections that follow. Sampling methods and protocols used in field data collection followed established methods, but were slightly modified in some cases. Sampling reach length for base parameter data collection was based on the bankfull width of the channel (**Table I-1**).

Table I-1. Base parameter reach lengths based on bankfull channel width.

Bankfull channel width	Reach length
<20 feet	800 feet
20 – 29.9 feet	1,000 feet
30-39.9	1,500 feet
40-49.9	2,000 feet
50-74.9 feet	3,000 feet
>75 feet	4,000 feet
<20 feet	800 feet

I.2.1 Cross Sections

Cross section measurements were collected using standard methods as described by Rosgen (1996). Cross sections were measured at five riffle locations along each sampling reach. Channel morphology measures from each cross section included channel bankfull width, maximum bankfull depth, and floodprone width. Cross section measurements are used to calculate cross sectional area, mean bankfull depth, channel entrenchment, and width-to-depth ratio. Cross section measurements were also used to determine the Rosgen channel type of each reach.

I.2.2. Riparian Line Transect

The riparian assessment was based on methods described by Winward (2000). At each of the five cross section stations, crews measured riparian cover types across the floodprone width. If the floodprone width extended greater than 100 feet from each bank, riparian vegetation was measured for 100 feet from the bankfull channel margin on both left and right banks. Cover types included bare ground, herbaceous, and woody vegetation. Vegetation zones included ground cover (<0.5 meters), understory (0.5 - 5 meters), and overstory (>5 meters).

I.2.3 Morphology/Habitat Profile

This portion of the base parameter field assessment involved collecting data on channel morphology features (i.e. pools, run, riffles, glides), habitat unit lengths, and large woody debris locations, aggregations, and diameters. These measurements allow calculation of pool density, pool/riffle ratios, residual pool depths and volumes, and large woody debris density. Measurements were collected as described by Rosgen (1996) and Kershner et al. (2002). Channel habitat measures included:

- Habitat unit lengths
- Pool widths
- Maximum pool depth
- Pool crest depth
- Presence of undercut banks
- Large woody debris count
- Large woody debris aggregate count

I.2.4 Pebble Counts

Pebble counts were used to collect data on sediment gradations from representative riffles, pools, and bars for each assessment site. A modified Wolman pebble count (Wolman 1954) was used to determine particle size distribution within riffles, runs, and pools. Field personnel collected sediment particle size information using a gravelometer from 100 locations representative of each morphologic type. Particles were measured along their intermediate axis (B-axis, **Figure I-1)**. The results were then used to determine the cumulative particle size distribution, including the percent <2mm and <6mm representative of riffles, bars, and pools from each assessment site.

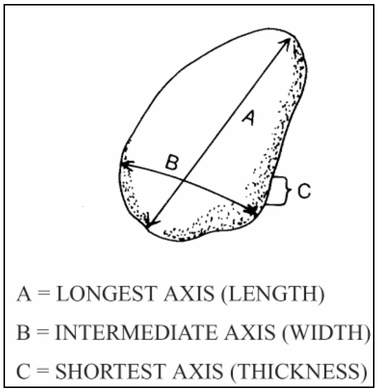

Figure I-1. Intermediate axis measurement (from Harrelson et al. 1994).

I.2.5 Percent Fines in Pool Tails

Bed morphology features referred to as “glides” or “pool tail-outs” are typically associated with the early life stage habitat of salmonids. The amount of fine sediment accumulation upon the surface of these bed features was evaluated using the 49-point grid toss method**.** The metal lattice, excluding the perimeter of the grid, forms a total of 49 interior grid intersections, and the grid intersections are approximately 6mm (**Figure I-2**). Within each pool tail, the metal grid was randomly tossed four times. After each toss, the grid intersections were evaluated in order to count how many grid intersections had sediment particles directly below them that were smaller than the (6 mm) intersections of the grid. The total number of evaluations varied depending on the number of pool tails per assessment reach.

Figure I-2. Grid design used for grid tosses to determine percent fines in pool tails.

I.3 Raw Data

The following tables contain raw data collected during sampling in 2004.

Table I-2. Cross section measurements and calculations.

Reach Name	Transect	Bankfull Width (ft)	Max Bankfull Depth (ft)	Mean Bankfull Depth (ft)	W/D Ratio	Entrenchment Ratio	Floodprone Width (ft)
SR02	A	13.0	1.1	0.8	17.3	3.1	40.0
SR02	B	14.0	1.5	0.7	19.2	1.8	25.5
SR02	C	18.5	1.3	1.0	17.7	2.4	43.5
SR02	D	21.7	1.1	0.8	26.9	2.2	48.7
SR02	E	16.5	1.1	0.5	34.0	2.5	40.5
SR02R	A	14.0	2.1	1.2	11.2	2.9	40.0
SR02R	B	13.8	1.6	1.1	12.7	2.1	29.2
SR02R	C	19.0	1.8	1.2	15.4	5.3	100.0
SR02R	D	13.8	1.5	1.0	13.8	2.4	32.8
SR02R	E	16.3	1.0	0.7	24.8	2.6	42.2
SR04	A	29.0	2.0	1.5	19.8	4.4	129.0
SR04	B	15.5	2.5	1.3	12.2	7.6	117.5
SR04	C	30.4	1.7	0.9	33.3	3.3	100.0
SR04	D	36.0	1.3	1.1	33.9	1.1	40.0
SR04	E	37.0	1.7	0.6	65.6	1.1	41.0
SR07	A	30.0	1.7	1.2	25.9	2.3	69.7
SR07	B	35.5	1.7	1.0	34.4	2.8	100.0
SR07	C	43.0	2.0	1.2	34.8	2.3	100.0
SR07	D	39.2	1.6	1.0	39.4	2.6	100.0
SR07	E	21.3	1.4	1.1	18.8	2.8	59.3
SR10	A	34.9	2.9	1.8	19.4	2.9	100.0
SR10	B	72.0	2.2	0.7	99.0	2.8	200.0
SR10	C	63.4	1.4	0.9	74.1	3.2	200.0
SR10	D	50.0	1.9	1.3	39.2	4.0	200.0
SR10	E	33.0	1.8	1.4	23.1	3.5	117.0
SR11	A	39.8	1.9	1.3	30.9	4.7	189.0
SR11	B	47.0	2.9	1.5	31.3	1.5	70.5
SR11	C	53.5	4.6	1.5	35.1	1.4	77.5
SR11	D	33.5	1.9	1.3	26.0	3.1	102.5
SR11	E	46.0	1.6	0.9	49.9	1.3	58.0
SR14	A	48.0	2.2	1.7	28.7	2.1	100.0
SR14	B	52.0	1.8	1.0	54.3	1.1	56.7
SR14	C	50.0	1.5	1.1	46.5	2.0	100.0
SR14	D	54.0	1.4	0.9	61.1	1.9	100.0
SR14	E	46.2	1.9	1.1	40.4	2.2	100.0
SR17	A	63.8	1.9	1.0	60.9	1.6	100.0
SR17	B	62.6	2.5	1.1	55.3	1.5	96.0
SR17	C	69.0	2.6	1.5	47.0	1.4	95.2
SR17	D	113.0	2.5	1.4	81.5	0.9	100.0

Table I-2. Cross section measurements and calculations.

Reach Name	Transect	Bankfull Width (ft)	Max Bankfull Depth (ft)	Mean Bankfull Depth (ft)	W/D Ratio	Entrenchment Ratio	Floodprone Width (ft)
SR17	E	64.0	2.4	1.6	41.0	2.6	166.0
SR20	A	53.5	3.1	1.5	35.2	1.9	100.0
SR20	B	75.0	3.3	1.7	42.9	1.1	85.8
SR20	C	74.3	2.4	1.4	51.7	1.2	85.6
SR20	D	82.0	2.4	1.9	43.1	1.1	88.9
SR20	E	95.4	2.4	1.6	59.8	1.0	100.0
SR22	A	69.5	2.9	2.3	30.6	2.4	169.5
SR23	B	66.0	2.4	1.6	40.2	2.5	166.0
SR24	C	64.0	2.3	1.7	36.8	1.6	105.0
SR25	D	76.0	3.6	1.5	49.5	2.6	200.0
SR26	E	92.0	2.1	1.3	70.8	1.2	112.0
PT05	A	6.8	1.8	1.2	5.6	10.9	74.0
PT05	B	27.5	2.0	1.4	19.9	1.9	53.5
PT05	C	7.0	1.6	1.2	5.9	19.3	135.0
PT05	D	5.0	1.4	1.2	4.3	40.0	200.0
PT05	E	6.0	1.8	1.1	5.2	2.8	17.0
PT07	A	11.0	2.2	1.7	6.4	18.2	200.0
PT07	B	15.0	1.7	1.4	10.8	13.3	200.0
PT07	C	5.5	1.6	1.1	4.8	21.4	117.7
PT07	D	16.0	2.1	1.3	11.9	12.5	200.0
PT07	E	7.0	1.8	1.2	5.6	28.6	200.0
PT08	A	13.5	1.4	1.0	13.3	2.6	35.0
PT08	B	14.0	1.5	1.3	10.7	1.7	24.0
PT08	C	14.0	1.7	1.3	10.7	1.9	27.0
PT08	D	13.5	1.8	1.4	9.7	1.1	15.0
PT08	E	13.0	1.6	1.4	9.6	2.2	28.0
PT08R	A	13.9	1.4	1.0	13.7	2.0	28.4
PT08R	B	17	1.4	1.1	15.7	0.8	14.4
PT08R	C	12.7	1.4	1.3	10.1	1.4	18.2
PT08R	D	12.3	1.3	1.2	10.5	1.2	14.5
PT08R	E	12.8	1.5	1.2	11.1	2.2	28.6
AC04	A	4	0.9	0.6	6.6	1.6	6.5
AC04	B	5.1	0.7	0.4	14.3	3.5	19.4
AC04	C	7	1.9	1.1	6.4	11.3	79
AC04	D	6.3	1.3	0.8	7.8	11.2	70.3
AC04	E	6	1.4	1.0	5.9	10.6	63.5
AC07	A	6.4	2.3	1.5	4.2	15.6	100
AC07	B	10.8	3.0	1.7	6.5	9.3	100
AC07	C	11.9	2.6	1.2	9.6	8.4	100
AC07	D	6.2	2.2	1.5	4.1	16.1	100
AC07	E	7.3	2.0	1.3	5.6	5.5	40.3

Table I-3. Percent fines in riffles.

Reach	% <2mm	% <6mm
SR02R	27	32
SR04	10	14
SR07	7	10
SR10	3	4
SR11	1	1
SR14	0	0
SR17	5	13
SR20	2	2
SR22	0	3
PT07	27	32
PT08	29	30
PT08R	79	87
AC07	22	56

Table I-4. Pool grid toss results. ND = no data

Site	Toss1	Toss2	Toss3	Toss4	Total % Fines
SR02	44	45	42	48	91
SR02	42	2	5	49	50
SR02	49	47	49	49	99
SR02	49	43	49	49	97
SR02	47	48	49	46	97
SR02R	23	46	43	47	81
SR02R	41	40	45	37	83
SR02R	49	47	46	39	92
SR02R	49	49	49	49	100
SR02R	47	49	49	46	97
SR02R	49	49	49	48	99
SR02R	48	46	41	49	94
SR02R	38	49	41	40	86
SR02R	49	48	44	49	97
SR04	44	47	35	8	68
SR04	34	26	7	7	38
SR04	12	4	11	7	17
SR04	6	3	7	11	14
SR04	4	13	3	5	13
SR04	0	3	9	15	14
SR04	45	43	6	8	52
SR04	45	39	20	5	56
SR04	3	2	25	30	31
SR04	3	1	0	0	2
SR07	4	7	9	11	16
SR07	48	49	45	46	96
SR07	2	2	1	2	4
SR07	12	5	6	7	15

Table I-4. Pool grid toss results. ND = no data

Site	Toss1	Toss2	Toss3	Toss4	Total % Fines
SR07	3	3	1	6	7
SR07	5	8	9	18	20
SR07	49	42	39	10	71
SR07	41	34	11	9	48
SR07	45	38	36	49	86
SR07	13	18	15	6	27
SR07	5	4	8	10	14
SR10	49	47	47	48	97
SR10	7	43	44	34	65
SR10	4	9	49	8	36
SR10	49	49	49	49	100
SR10	44	47	46	47	94
SR10	9	1	13	49	37
SR10	10	11	10	37	35
SR10	3	4	6	49	32
SR10	7	8	1	1	9
SR11	49	49	49	49	100
SR11	49	36	42	44	87
SR11	49	44	28	14	69
SR11	49	47	45	49	97
SR11	49	45	17	35	74
SR11	41	41	39	36	80
SR11	21	49	47	40	80
SR11	48	42	48	49	95
SR14	49	49	49	49	100
SR14	36	47	49	49	92
SR14	49	49	49	49	100
SR14	33	4	4	16	29
SR14	47	49	49	49	99
SR14	23	11	0	19	27
SR14	40	40	29	27	69
SR14	49	49	10	20	65
SR14	47	48	47	44	95
SR14	45	47	49	49	97
SR14	47	43	42	44	90
SR14	41	10	36	41	65
SR14	43	24	12	20	51
SR17	46	47	42	39	89
SR17	47	43	12	45	75
SR17	49	49	49	49	100
SR17	49	49	42	39	91
SR17	4	45	42	39	66
SR17	30	18	31	40	61
SR17	49	40	49	14	78
SR17	40	31	31	7	56

Table I-4. Pool grid toss results. ND = no data

Site	Toss1	Toss2	Toss3	Toss4	Total % Fines
SR20	6	10	8	15	20
SR20	4	30	16	12	32
SR20	16	16	17	25	38
SR20	0	0	0	8	4
SR20	49	15	16	7	44
SR20	49	40	7	5	52
SR22	10	0	0	0	5
SR22	4	0	0	0	2
SR22	4	6	3	0	7
SR22	7	14	5	49	38
SR22	3	3	5	0	6
SR22	0	3	2	0	3
SR22	2	0	0	0	1
SR22	0	49	7	14	36
PTR05	ND	ND	ND	ND	ND
PTR07	49	49	49	49	100
PTR07	49	49	49	49	100
PTR07	49	49	49	49	100
PTR08	49	49	49	49	100
PTR08	49	49	49	49	100
PTR08	49	49	49	49	100
PTR08	49	46	48	44	95
PTR08	49	49	49	49	100
PTR08	49	49	49	49	100
PTR08	49	49	49	49	100
PTR08R	49	49	49	49	100
PTR08R	49	49	49	49	100
PTR08R	49	49	49	49	100
PTR08R	49	49	49	49	100
PTR08R	49	49	49	49	100
PTR08R	49	49	49	49	100
PTR08R	49	49	49	49	100
PTR08R	49	49	49	49	100
PTR08R	49	49	49	49	100
AC04	ND	ND	ND	ND	ND
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100

Table I-4. Pool grid toss results. ND = no data

Site	Toss1	Toss2	Toss3	Toss4	Total % Fines
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100
AC07	49	49	49	49	100

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